DOCUMENT RESUME

ED 149 729 IR 005 510

TITLE	Satellite-Based Educational Services. Technical Memorandum.
INSTITUTION	Operations Research, Inc., Silver Spring, Md.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C. Finance and Productivity Group. Technical Applications Div.
PUB DATE	31 May 77
CONTRACT	400-76-0132
NOTE	72p.; Some figures and illustrations are of marginal legibility
EDRS PRICE	MF-$0.83 HC-$3.50 Plus Postage.
DESCRIPTORS	*Communication Satellites; *Comparative Analysis; Cost Effectiveness; Delivery Systems; *Educational Television; *Engineering Technology; Space Sciences

ABSTRACT

This memorandum contains engineering information relevant to the use of communication satellites for educational purposes. Information is provided for ground terminals as well as satellites. Satellite related issues addressed include: (1) expected life of service of various satellites, (2) constraints on the availability of the satellites, (3) comparisons of their technical capabilities and geographic coverage patterns, and (4) speculation on future commercial satellite configurations. Information related to ground terminals includes: (1) costs associated with resiting existing terminals, (2) costs of purchasing new terminals, and (3) costs of converting existing terminals to operate with various satellites. Numerous maps, charts, tables, and graphs are provided. (Author/STS)

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SILVER SPRING, MARYLAND

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TECHNICAL MEMORANDUM
SATELLITE-BASED EDUCATIONAL SERVICES

31 May 1977

PREPARED UNDER CONTRACT No. 400-76-0132
FOR NATIONAL INSTITUTE OF EDUCATION
TECHNOLOGICAL APPLICATIONS DIVISION

IR005510

FOREWORD

This memorandum contains engineering information relevant to the use of communication satellites for educational applications. In particular, specific questions are addressed regarding both satellites and ground terminals. With regard to satellites, the questions relate to the availability and characteristics of various satellites which have the potential for educational applications. With regard to ground terminals, the questions relate to costs associated with resiting existing terminals, purchasing new terminals and converting existing terminals to operate with various satellites. Also cost trends for ground terminals in the next decade are addressed.

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I. SATELLITE VEHICLES

This section addresses the availability and engineering characteristics of various satellite vehicles which have the potential for use in educational applications. Various topics are addressed in the form of specific questions around which this memorandum is organized. At the outset, it should be pointed out that the answers to each of the questions which are individually posed must necessarily include consideration of related equipments. For example, the technical capabilities of a satellite vehicle, per-se, cannot be considered without attention to its associated Ground Terminals and intended operational duties.

I-1 What is the expected life of service of ATS-6? of CTS? of ATS-1 and ATS-3?

Figure 1 depicts all possible useful satellites in the '76 to '85 time frame. The figure does not consider the possibility of catastropic failure. On ATS-6, the nature of the failures which have occurred have been related to stationkeeping functions, such as to require an increase in required fuel consumption - the projections available at this time, are for three to four more years of expected life.

On CTS, the same types of failures have occurred which require substantial increases in the use of stationkeeping fluid. Optimistic estimates of remaining useful life are in the range of one to two years.

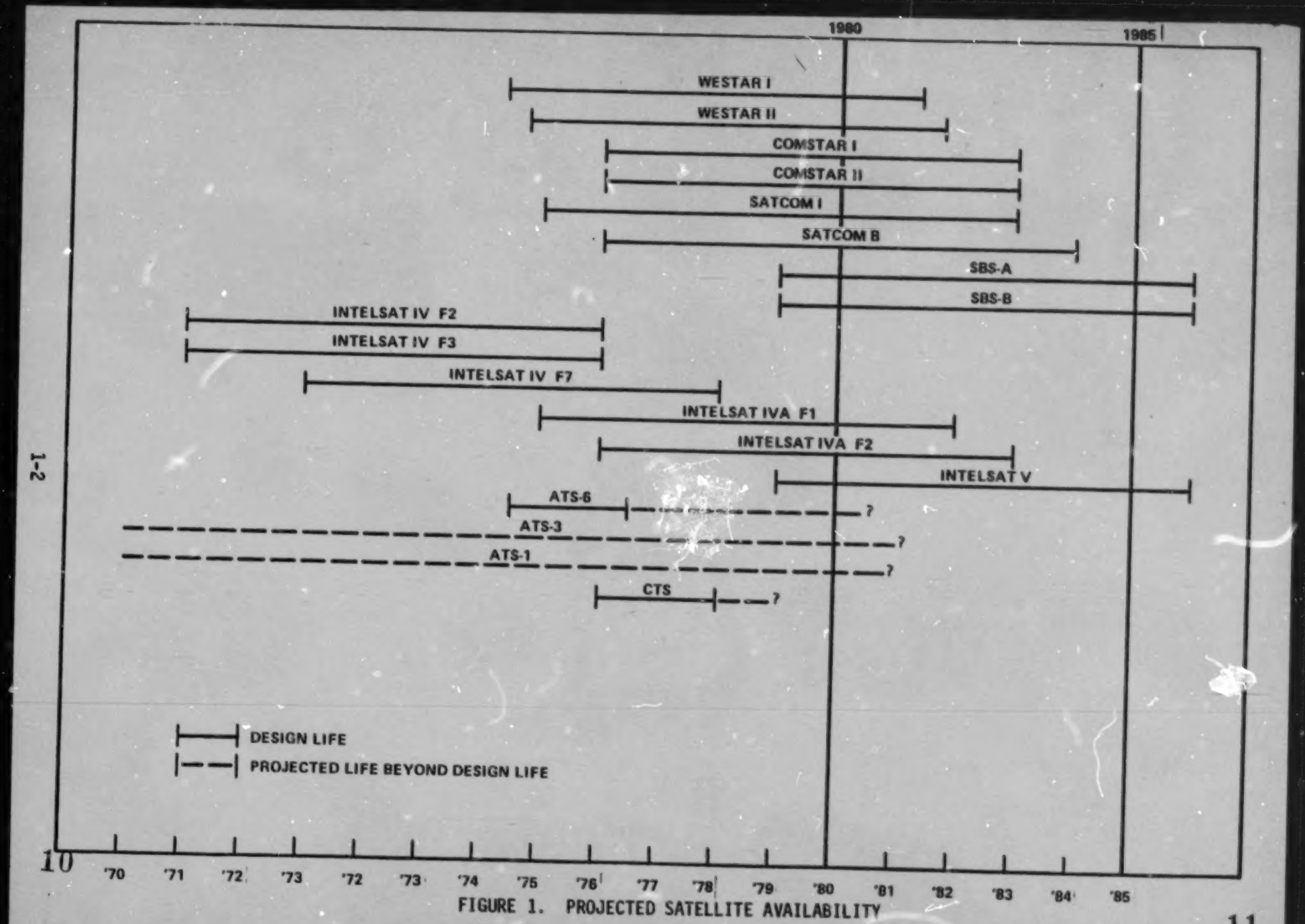


FIGURE 1. PROJECTED SATELLITE AVAILABILITY

ATS-1, although out of fuel, has experienced very little solar cell degradation. This, in combination with the nearly "new" condition of its batteries has resulted in a projected continuing lifetime capability of as many as five more years - however, NASA may decide to "turn-off" the ATS-1 satellite.

ATS-3 is currently being moved to a new location. It is believed that enough fuel remains to effect a repositioning at 105°W. As in the case of ATS-1, projections of continued capability for this satellite are as long as five more years. NASA, however, may decide to "turn it off".

I-2 What are the constraints on the availability of each of the ATS satellites, of CTS, and of useable Commercial satellites?

The physical availability of these satellites is depicted in Figure 1. The information relating to future commercial satellites is based upon current planned launch dates and of course, design lifetime. The availability of the Commercial satellites, in practical terms depends upon constraints which may exist in terms of Earth Station receive and transmit size limitations, and other factors which are to be considered in an upcoming seminar which is addressed to this topic in particular.

The ATS-1 is presently being used very heavily, and those to whom this service is now available, wish to continue to use the ATS-1 satellite as long as possible. It would appear then, that the availability of this satellite for new users or purposes would be severely limited.

The ATS-3 satellite, on the other hand, is not used nearly so heavily as the ATS-1, and, at least at this point in time, it would appear that at least some limited availability could be expected.

ATS-6 presently has as many as twenty-eight "new" experimenters lamoring to be allowed to use it. Under these circumstances, the ability of those who are presently suing ATS-6, to expand their experiments, demonstrations and uses is likely to be severely constrained. Moreover, since this satellite has already met its design lifetime goal, it would not be practical to invest in much new equipment whose use would be limited to ATS-6. The same general admonition would of course be appropriate for the ATS-1

and 3 satellites as well.

The CTS project office has already reported scheduling and access problems due to the great demand for services from this satellite. This in itself would not preclude additional experiments access, but as a practical matter, much of the flexibility required in an experimental or demonstration project would be unavailable.

I-3 Provide detailed comparisons of the technical capabilities and geographic coverage patterns of all Satellites, NASA, and Commercial, suitable for Educational use.

The question is addressed by formulating the information which was gathered on each of the satellites listed, in the format of a separate figure. All information which would be appropriate for an evaluation of each of the satellites' capability to provide Educational Network services is included. Here again, it should be borne in mind that claimed performance and capacity is in most cases predicated on particular Earth terminal characteristics and operational scenarios to actually assess the utility of a given satellite in an Educational TV Relay network, one must evaluate uplink, and downlink power budget analyses, and the required connectivity.

The particular spacecraft addressed are:

WESTAR (Western Union System)	Figure 2
SATCOM (RCA System)	Figure 3
CONSTAR (Comsat System)	Figure 4
SBS (Satellite Business Systems)	Figure 5
INTELSAT	Figure 6, 7 & 8
ATS-1	Figure 9
ATS-3	Figure 10
ATS-6	Figure 11
CTS	Figure 12

I-4 What will be the most probable Commercial Satellite Configuration in 1980? In 1985?

Refering to Figure 1, for 1980, the most likely configuration of Commercial satellites would be as depicted therein; namely two each of WESTAR, CONSTAR, SATCOM operating in the C-Band frequency range, and two SBS satellites operating in the K-band range. Three INTELSAT's are included insofar as they are theoretically and technically able to provide the required service. The intended orbital locations may be readily determined from the information contained in Figures 2 through 12.

Insofar as the 1985 time frame is concerned, the accuracy of predictions is diminished, and based upon present knowledge, only the two SBS and two INTELSATS can be counted on at this time. However, it does not require a great feat of prognostication to say with some assurance, that at least one each of the WESTAR, COMSTAR and SATCOM series will be on orbit, and operating in that time frame.

Table 1 summarizes the important parameters of the space systems reported on in Figures 2 through 12.

TABLE 1.1

SUMMARIZATION OF SPACE SYSTEMS PARAMETERS

DESIGN LIFE	WESTAR 7	SATCOM 8	COMSTAR 7	SBS 7	INTELSAT 7	CTS 2	ATS-1 2	ATS-3 2	ATS-6 2
EIRP	33 dBw/ single carrier	32 dBw	31 dBw	43 to 48 dBw	34 dbw @ C 47 dBw @ K } V 22 to 29 } IV	50/59	17	17	44.5 min
Capacity	1 video 1220 VC/ xpond 60 MBS/ xpond	24 x-ponders 1 video per x-ponders 900 VC per xpond or 50 MBPS	24 x-ponders @ 1200 VX per	8 x-ponders @ 41 MB/trans-ponder	22,000 VC } V 1100/ 1300 VC } IV	2 way video & audio	2VC	2VC	1 video + 4 audio
Frequency Band	C-band	C-band	C-band	K-band	K-band & C-band } V C-band } IV	K-band	149/135	149/135 MHz	2.5 GHz & 4/6 GHz
Coverage	conus/ part of Alaska	conus/ part of Alaska	Multi-ple beam conus/ Alaska & Hawaii	conus	hemisphere & spot beam	conus & part of Alaska	E.C.	E.C.	at 2.5 GHz 2 foot-prints of 500x300 miles E.C. @ C-Band

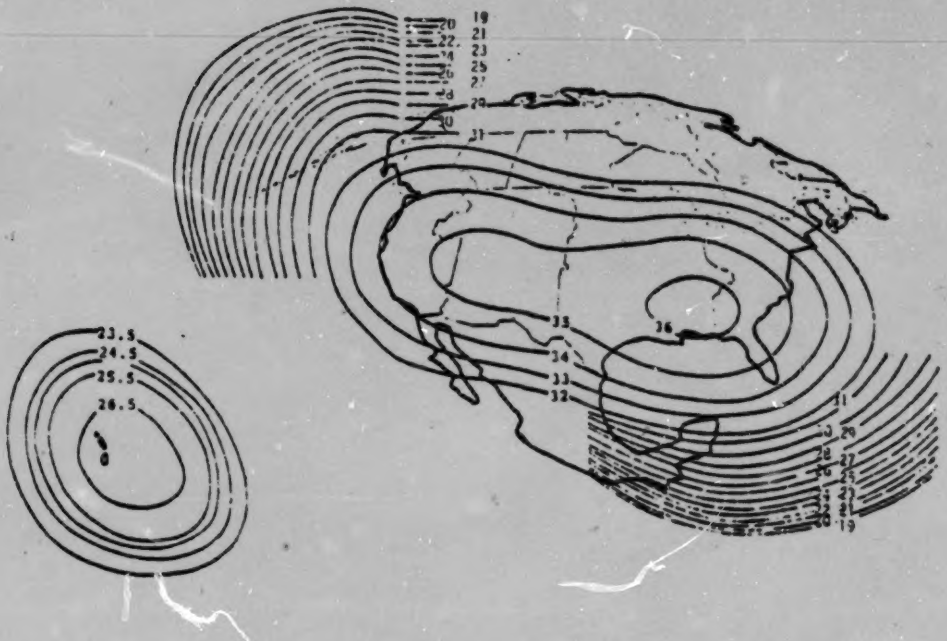
FIGURE 2
WESTERN UNION SYSTEM

1. Satellite name, location, and launch date.

	WESTAR I	99°W	Apr. 13, 1974
(spare)	WESTAR II	123.5°W	Oct. 9, 1974

2. Design life - 7 years.

3. Geographical Coverage



WESTAR I EIRP CONTOUR COVERAGE (dBW) AT 99° W. LONG. (3720 MHz)

4. Frequency Spectrum

FREQUENCY AND POLARIZATION PLAN

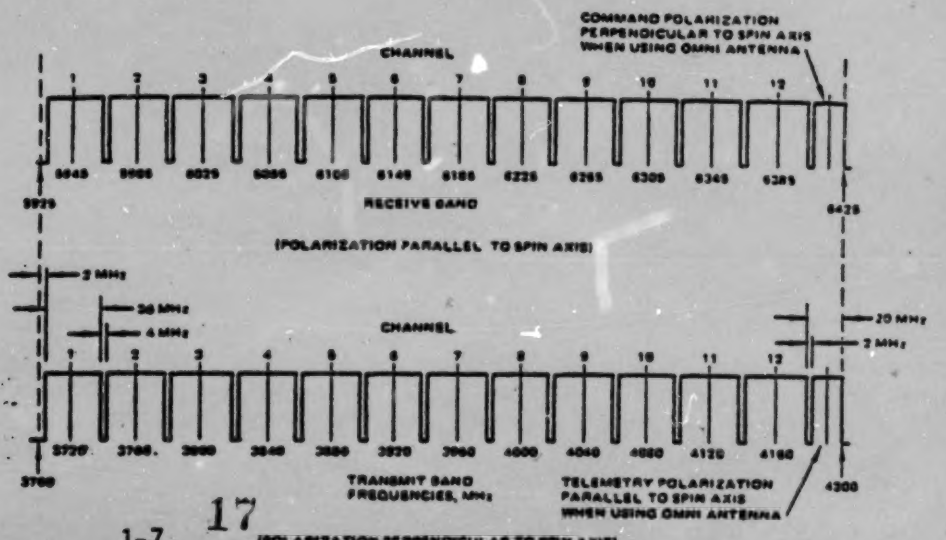
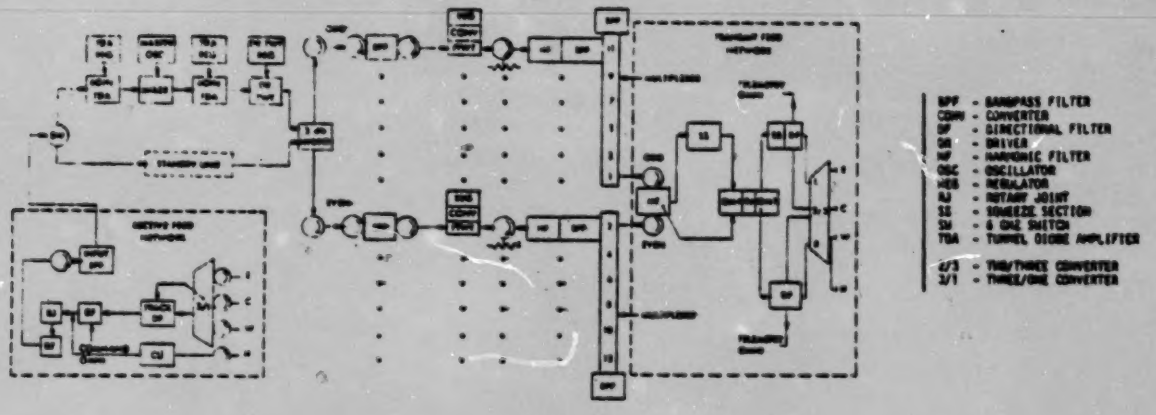

COMMAND POLARIZATION PERPENDICULAR TO SPIN AXIS WHEN USING OMNI ANTENNA
CHANNEL
1 2 3 4 5 6 7 8 9 10 11 12
5945 5985 6025 6065 6105 6145 6185 6225 6265 6305 6345 6385
5925
6425
RECEIVE BAND
(POLARIZATION PARALLEL TO SPIN AXIS)
2 MHz
30 MHz
4 MHz
CHANNEL
20 MHz
2 MHz
1 2 3 4 5 6 7 8 9 10 11 12
3720 3760 3800 3840 3880 3920 3960 4000 4040 4080 4120 4160
3700
4200
TRANSMIT BAND FREQUENCIES, MHz
TELEMETRY POLARIZATION PARALLEL TO SPIN AXIS WHEN USING OMNI ANTENNA
(POLARIZATION PERPENDICULAR TO SPIN AXIS)

FIGURE 2
WESTERN UNION SYSTEM (CONT.)

5. EIRP - 33 dBW for single carrier in one 40 MHz slot; EIRP per carrier; 33 to -4.3 dBW per carrier.

6. Capacity - 12 transponders; 1 television signal/transponder, 1200 voice channels/transponder, 60 Mbps/transponder, in single carrier per transponder access mode; 2 carriers per transponder at 360 channels/carrier; 3 carriers/transponder at 180 channels/carrier; Earth station G/T at 4 GHz varies from 37.0 to 19.0 dB/°K; WESTAR system capacity limited only by capacity of satellite.

7. Block diagram of spacecraft



SATELLITE COMMUNICATION SYSTEM

Multiple carrier access to a transponder is available to customers leasing whole transponders.

Comment: there is also an on-the-ground spare.

Comment: WESTAR II is essentially an in-orbit spare but it is used for occasional services.

FIGURE 3
RCA SYSTEM

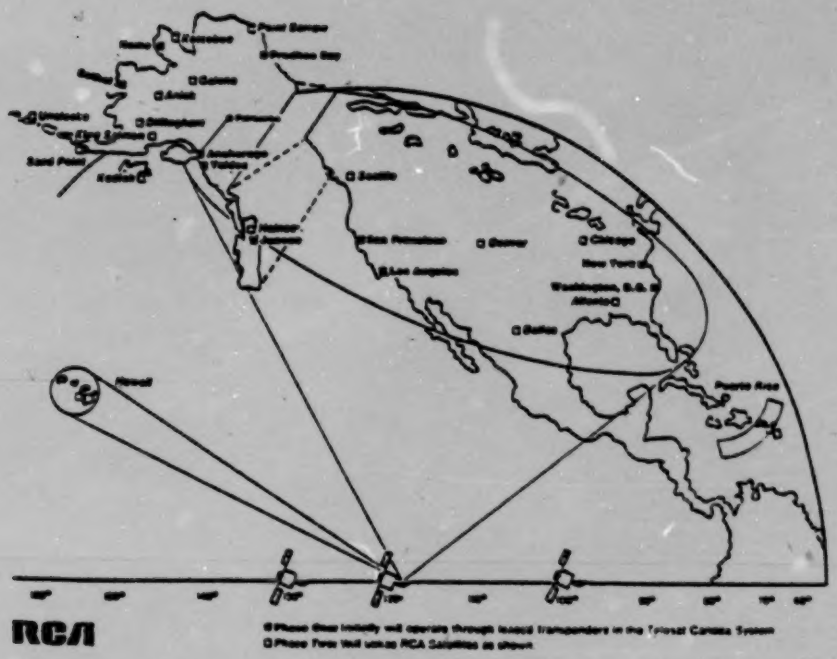
1. Satellite name, location, launch date

SATCOM I	135.8°W	1975
SATCOM B	119°W	1976
SATCOM C	91°W	undetermined

2. Design life - 8 years; the spacecraft operating survival probabilities with 20 transponders operational at the end of 7 and 8 years are 0.[illegible] and 0.5.

3. Coverage

RCA SATCOM SYSTEM COVERAGE



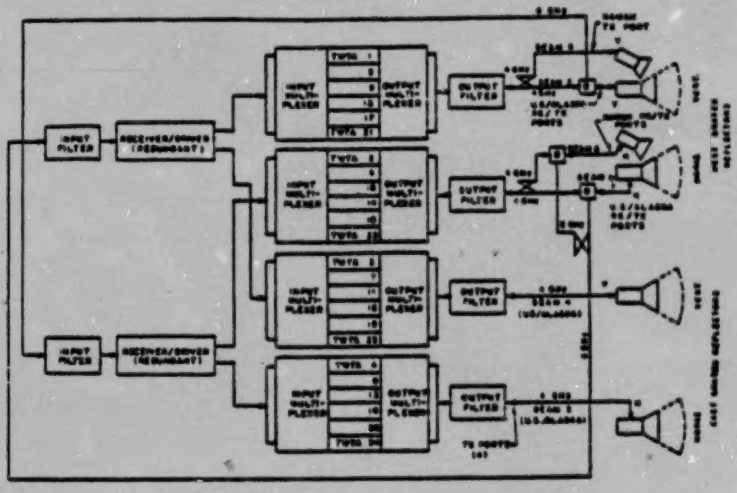
4. Frequency spectrum - frequency reuse is employed in order to establish 24 independent 34 MHz channels within the 500 MHz allocated band. The channels are spaced on 20 MHz centers, but are transmitted via alternately horizontal and vertical polarzations in order to isolate adjacent channels.

FIGURE 3
RCA SYSTEM (CONT.)

5. EIRP - 32 dBW peak to CONUS and ALASKA; 26 dBW peak to HAWAII.

6. Capacity - 24 transponders; 1 video channel/transponder, single carrier FM-TV of network quality; 900 voice channels/transponder, 50 Mbps data/transponder, single carrier per transponder.

7. Block diagram of Spacecraft and illustration of S/C.



COMMUNICATION SUBSYSTEM

RCA SATCOM
SATELLITE

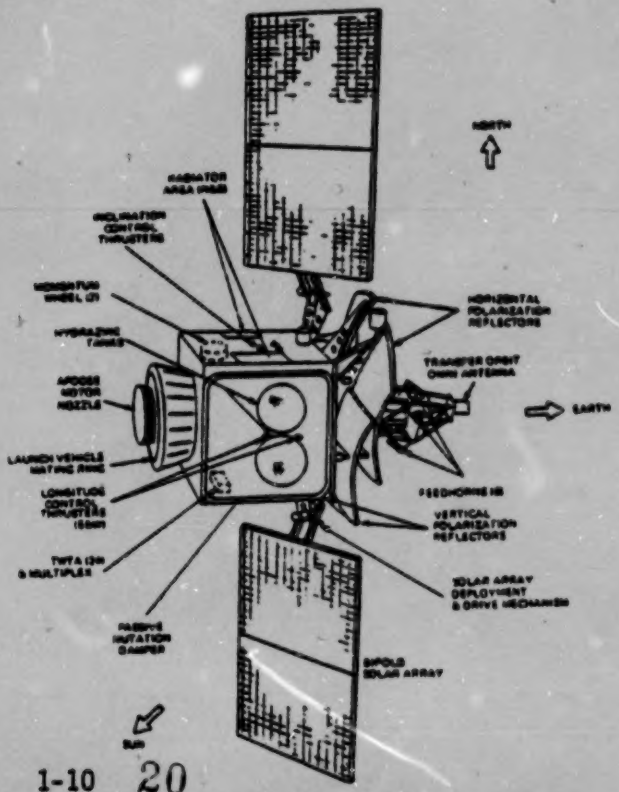


FIGURE 3
RCA SYSTEM (CONT.)

Comment: SATCOM C could be an in-orbit spare.

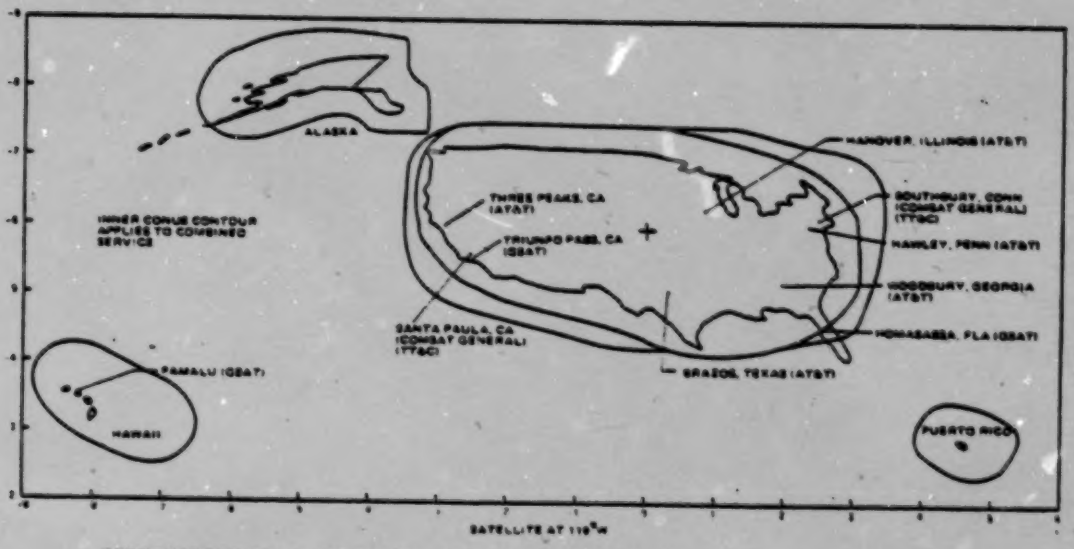
FIGURE 4
COMSAT SYSTEM

1. Satellite name, location, and launch date.

	COMSTAR II	95°W	1976
	COMSTAR I	128°W	1976
(spare)	COMSTAR C	89.7°W	undetermined

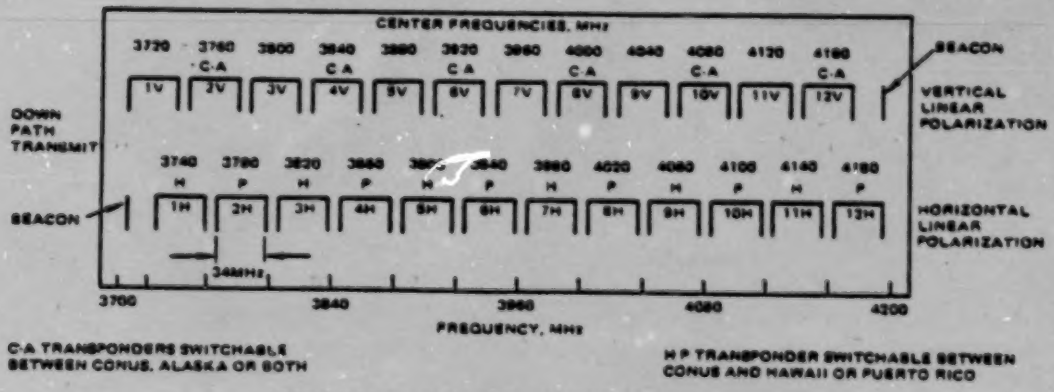
2. Design Life - 7 years

3. Geographical coverage



COMMUNICATIONS SERVICE AREAS AND PROPOSED GROUND STATIONS

4. Frequency Spectrum (downlink) - uplink is identical but 2225 MHz higher; 5925-6425 MHz.


CENTER FREQUENCIES, MHz
3720 3760 3800 3840 3880 3920 3960 4000 4040 4080 4120 4160
C-A
1V 2V 3V 4V 5V 6V 7V 8V 9V 10V 11V 12V
BEACON
VERTICAL LINEAR POLARIZATION
DOWN PATH TRANSMIT
3740 3780 3820 3860 3900 3940 3980 4020 4060 4100 4140 4180
H P H P H P H P H P H P H P
1H 2H 3H 4H 5H 6H 7H 8H 9H 10H 11H 12H
BEACON
HORIZONTAL LINEAR POLARIZATION
34MHz
3700 3840 3980 4080 4200
FREQUENCY, MHz
C-A TRANSPONDERS SWITCHABLE BETWEEN CONUS, ALASKA OR BOTH
H P TRANSPONDER SWITCHABLE BETWEEN CONUS AND HAWAII OR PUERTO RICO

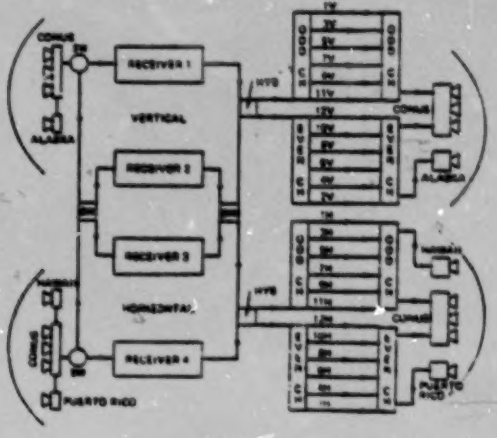
FREQUENCY AND POLARIZATION PLAN

FIGURE 4
COMSAT SYSTEM (CONT.)

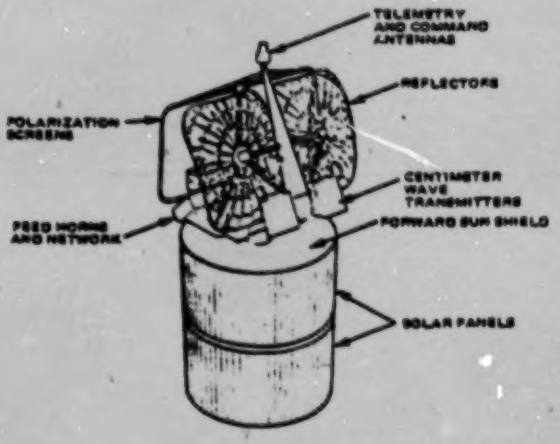
5. EIRP - 33 dBW to each individual beam; 31 dBW to combined CONUS-ALASKA coverage area.

6. Capacity - 24 transponders; maximum capacity of 1,200 voice circuits/transponder in single carrier FDM mode with a receiver ground terminal with G/T = 41 dB/^{o}K.

7. Spacecraft block diagram and illustration



REPEATER BLOCK DIAGRAM



SPACECRAFT CONFIGURATION

FIGURE 5
SBS SYSTEM

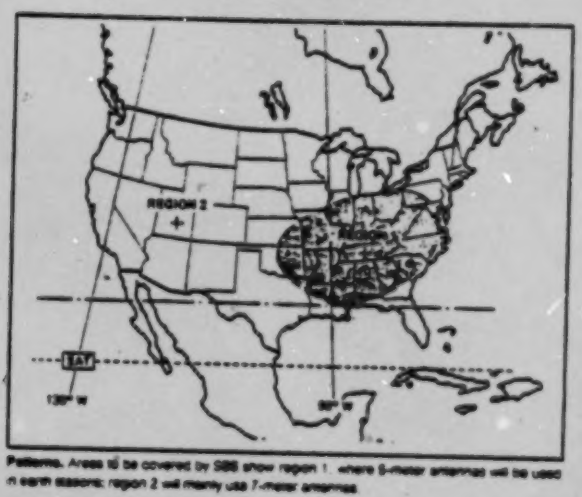
1. Satellite name, location, launch date

SBS-A	238°E (122°W)	1979
SBS-B	250°E (106°W)	1979

System to become operational in August 1979.

2. Design life - 7 years

3. Coverage



4. Frequency Spectrum

uplink - 14 GHz
downlink - 12 GHz

Eight transponders, each with a useful bandwidth of 54 MHz capable of being accessed by time division multiple access.

5. EIRP - 43 dBW to 38 dBW.

6. Capacity - 41 Mbps/transponder; 54 MHz transponders.

FIGURE 5
SBS SYSTEM (CONT.)

7. Block Diagram

not available

To offset signal attenuation in Region 2 due to heavy rainfall, larger 7-meter antennas supported by high-powered amplifiers ranging from several hundred to 2 kilowatts will be used for digitized voice, image, and data system; estimated cost of ground station - $474,000.

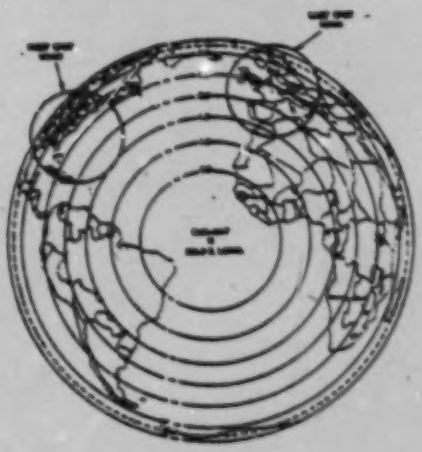
FIGURE 6
INTELSAT IV

1. Satellite name, location, launch date

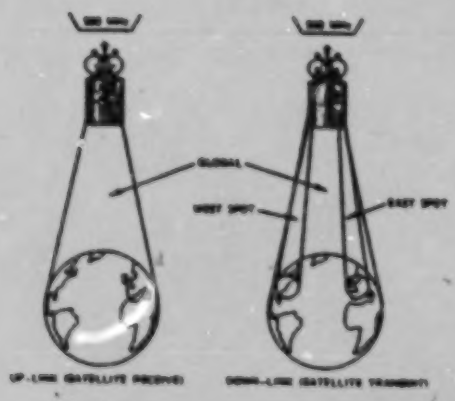
INTELSAT IV	F7	30.2°W (329.8°E)	1973
INTELSAT IV	F3	23.1°W (336.9°E)	1971
INTELSAT IV	F2	190W (341°E)	1971

2. Design Life - 7 years

3. Coverage



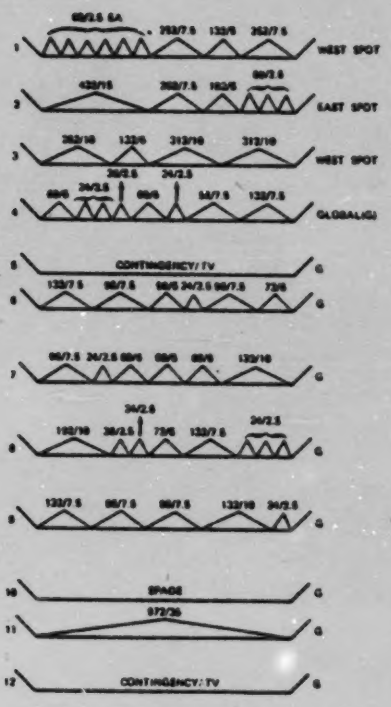
SPOT- AND GLOBAL-BEAM GAIN CONTOURS IN THE ATLANTIC REGION



INTELSAT IV ANTENNA COVERAGE CAPABILITY

FIGURE 6
INTELSAT IV (CONT.)

4.



TYPICAL INTELSAT IV FREQUENCY PLAN
(12 TRANSPONDERS)

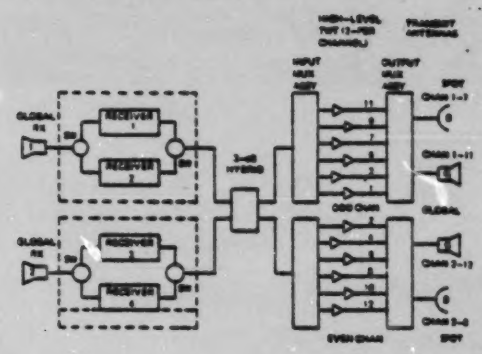
5. EIRP - 22.0 dBW, Global Beam; 33.7 dBW, Spot Beam.

6. Capacity

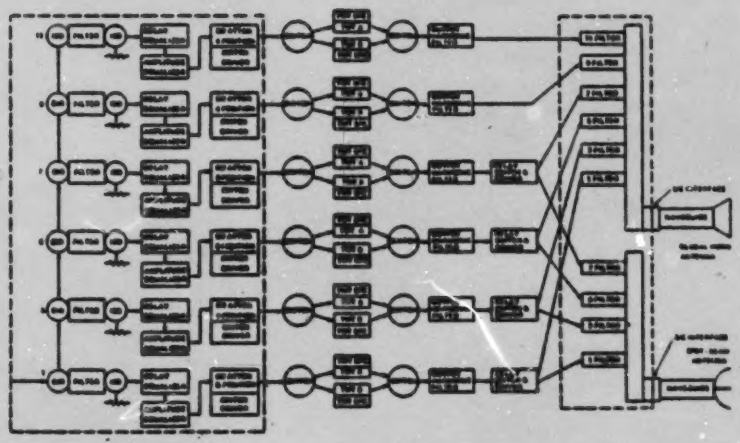
1 video channel/global transponder
2 video channels/spot transponder
540 audio channels/global transponder
1,400 audio channels/spot transponder

FIGURE 6
INTELSAT IV (CONT.)

7. Block Diagram of S/C



TRANSPONDER BLOCK DIAGRAM



BLOCK DIAGRAM OF CHANNELIZED SECTION

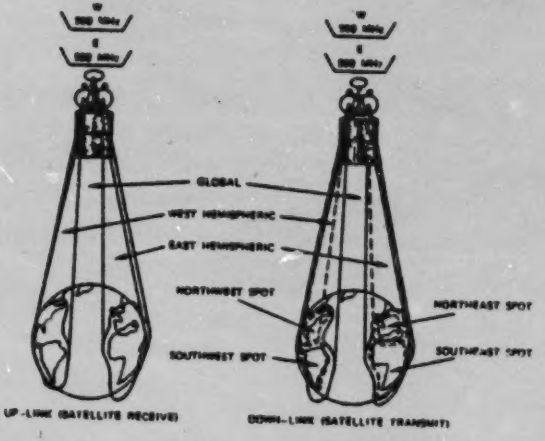
FIGURE 7
INTELSAT IV A

1. Satellite name, location, launch date.

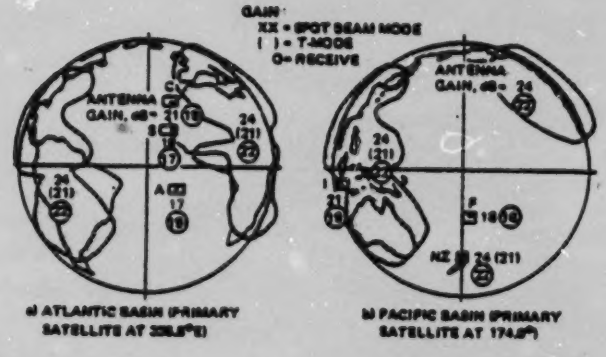
INTELSAT IV A	F2	29.5°W (330.5°E)	1976
INTELSAT IV A	F1	21.5°W (338.5°E)	1975

2. Design Life - 7 years

3. Coverage



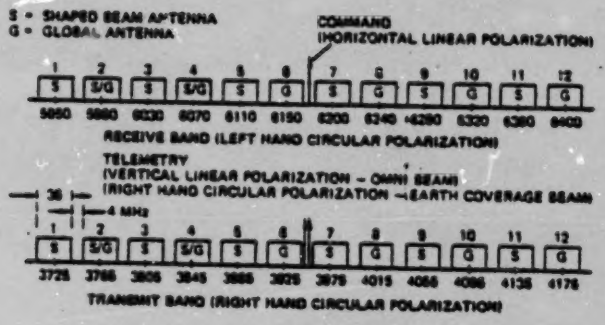
INTELSAT IV-A ANTENNA COVERAGE CAPABILITY



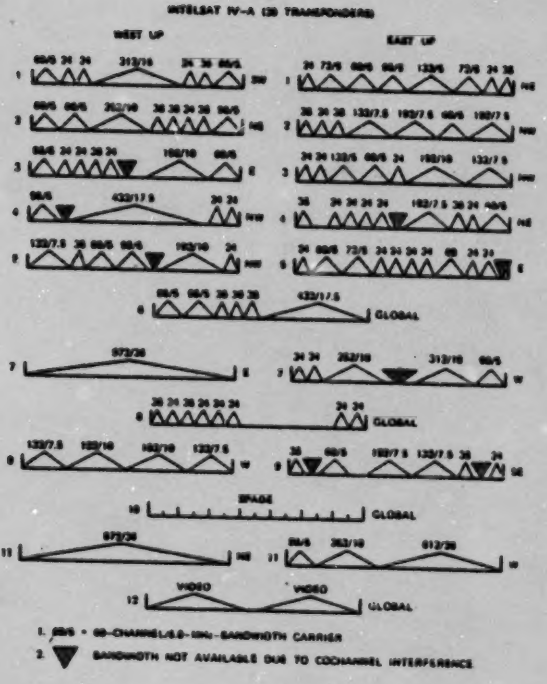
SHAPED BEAM COVERAGE

FIGURE 7
INTELSAT IV A (CONT.)

4. Frequency Plan


S = SHAPED BEAM ANTENNA
G = GLOBAL ANTENNA
COMMAND
(HORIZONTAL LINEAR POLARIZATION)
1 2 3 4 5 6 7 8 9 10 11 12
S S/G S S/G S G S G S G S G
5950 5990 6030 6070 6110 6150 6200 6240 6280 6320 6360 6400
RECEIVE BAND (LEFT HAND CIRCULAR POLARIZATION)
TELEMETRY
(VERTICAL LINEAR POLARIZATION – OMNI BEAM)
(RIGHT HAND CIRCULAR POLARIZATION – EARTH COVERAGE BEAM)
36
4 MHz
1 2 3 4 5 6 7 8 9 10 11 12
S S/G S S/G S G S G S G S G
3725 3765 3805 3845 3885 3925 3975 4015 4055 4095 4135 4175
TRANSMIT BAND (RIGHT HAND CIRCULAR POLARIZATION)

FREQUENCY AND POLARIZATION PLAN



TYPICAL INTELSAT IV-A FREQUENCY PLAN (20 TRANSPONDERS)

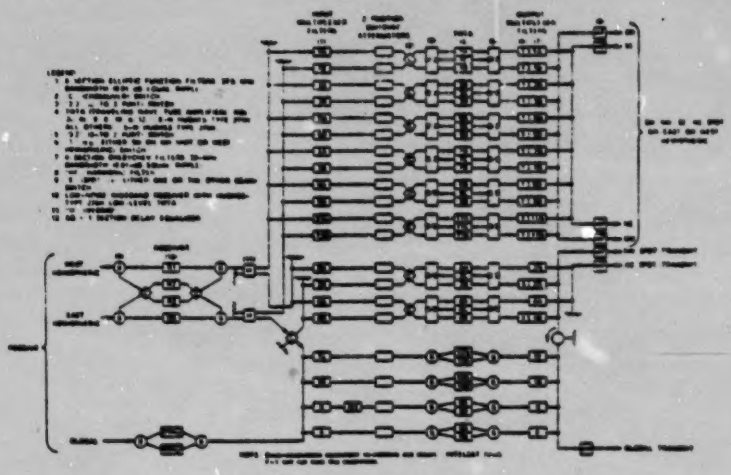
FIGURE 7
INTELSAT IV A (CONT.)

5. EIRP - 29 dBW, spot beam; 26 dBW, hemisphere beam; 22 dBW, global beam.

6. Capacity - 1,300 voice channels/spot transponder; 1,100 voice channels/ hemisphere transponder; capacity is bandwidth limited.

Ground Terminal G/T is required to be 6 dB better than those used with INTELSAT IV, in order to obtain same performance.

7. Block Diagram



INTELSAT IV-A BLOCK DIAGRAM

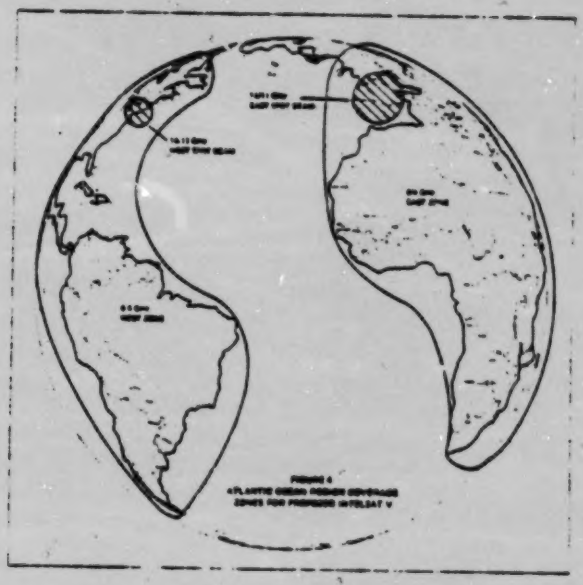
FIGURE 8
INTELSAT V

1. Satellite name, location, launch data.

   INTELSAT V - Atlantic Ocean 1979

2. Design life - 7 years

3. Coverage



ATLANTIC OCEAN REGION COVERAGE
ZONES FOR PROPOSED INTELSAT V

4. Frequency Spectrum

   uplink 14.0-14.5 GHz; downlink 10.95-11.2 GHz and 11.45-11.7 GHz.

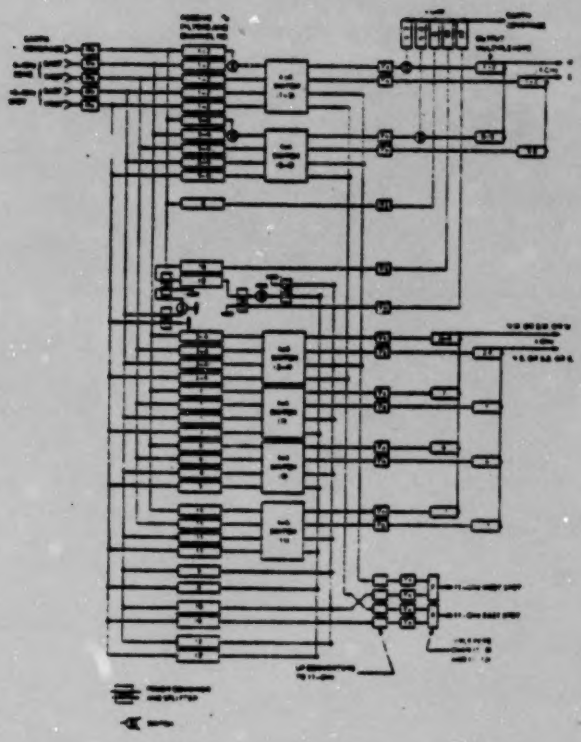
   uplink 6 GHz; downlink 4 GHz.

5. EIRP - 31 dBW, global beam (C-band); 34 dBW, hemisphere beam (C-band); 47 dBW, spot beam (K-band).

6. Capacity - 22,000 voice channels, total.

FIGURE 8
INTELSAT V (CONT.)

7. Block Diagram



EXAMPLE OF EXAMPLE OF COMMUNICATIONS SIGNAL PATH DIAGRAM
FOR INTELSAT V (WITHOUT REDUNDANCY SHOWN)

FIGURE 9
ATS-1

1. Satellite name, location, launch date

   ATS-1 $211^{o}E$ ($149^{o}W$) December 7, 1976

2. Projected Life - late 1980 unless "turned off".

3. Coverage - Earth Coverage

4. Frequency Plan

   Uplink: 149 MHz

   Downlink: 135 MHz

   Center Frequencies: Channel A - 135.575 MHz
   Channel B - 135.625 MHz

5. EIRP - 17 dBw peak

6. Capacity - 2 voice channels.

FIGURE 10
ATS-3

1. Satellite name, location, launch date

   ATS-3 $290^{o}E$ ($70^{o}W$) November 6, 1967

2. Projected Life - Expected to be useable until late 1980 unless "turned off".

3. Coverage

   Earth Coverage

4. Frequency Plan

   Uplink: 149MHz

   Downlink: 135MHz

   Center Frequencies: Channel A - 135.575 MHz
   Channel B - 135.625 MHz

5. EIRP - 17 dBw peak

6. Capacity - 2 voice channels

FIGURE 11
ATS-6

1. Satellite name, location, launch date

ATS-6 on its way to 140°W May 30, 1974

2. Design Life - 2 years

3. Coverage - at 2.5GHz: a pair of footprints each approximately 500 miles north to south by 300 miles east to west.

at 4/6GHz: earth coverage

VARIOUS POSITIONS FOR THE TWIN FOOTPRINTS OF THE ATS-6 2,500 MHz TRANSMITTERS SHOWN ON A MAP OF THE UNITED STATES: ONLY ONE PAIR OF FOOTPRINTS WILL BE TRANSMITTED AT ANY GIVEN TIME

4. Frequency Spectrum

Uplinks: Three 40 MHz channels at 6 GHz, center frequencies are 6350, 6150, and 5950 MHz. One 40 MHz channel at 2250 MHz.

FIGURE 11
ATS-6 (CONT.)

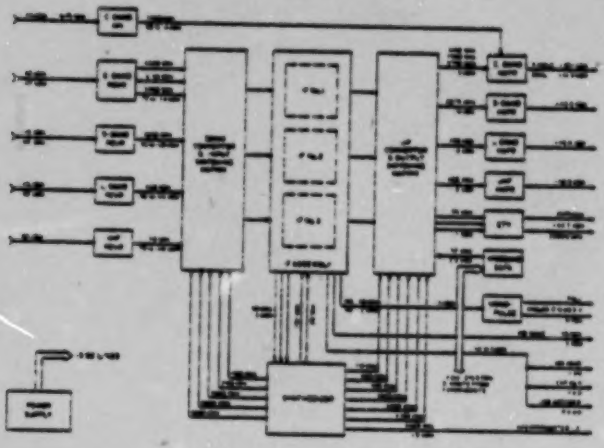
4. Frequency Spectrum (cont.)

Downlinks: Three 40 MHz channels at 4 GHz, center frequencies are 3950, 3750, and 4150 MHz. Two 40 MHz channels at 2.5 GHz, center frequencies are at 2569 and 2670 MHz.

5. EIRP - 52.5 dBw per channel peak to 44.5 dBw minimum at 2.5 GHz. 28.0 dBw peak to 25.0 dBw minimum at 4 GHz.

6. Capacity - 1 video plus 4 audio/channel.

7. Block Diagram and Illustration



SIMPLIFIED BLOCK DIAGRAM
OF THE COMMUNICATIONS SUBSYSTEM

ATS-6 ORBITAL (DEPLOYED)
CONFIGURATION

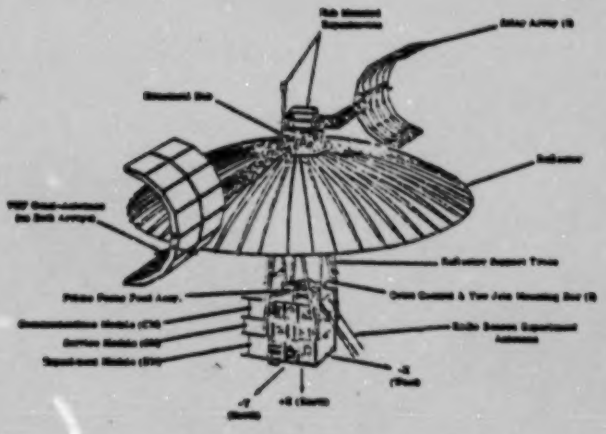


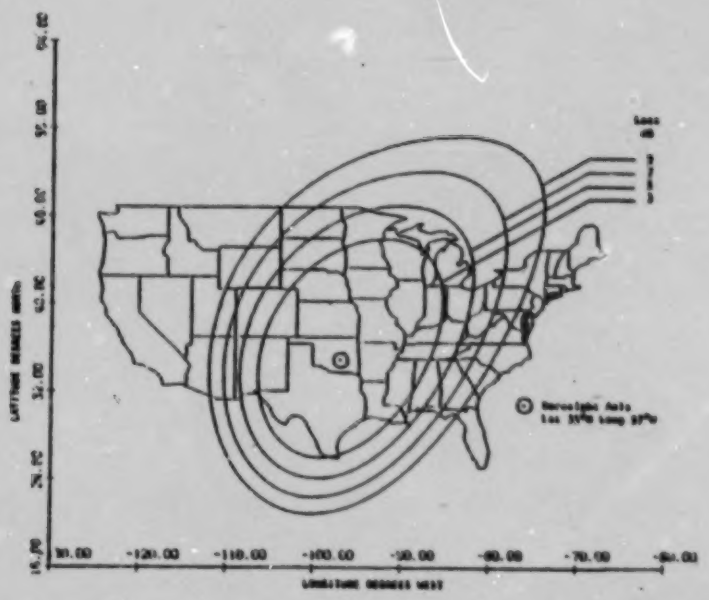
FIGURE 12
CTS

1. Satellite name, location, launch data

CTS	116°W	January 17, 1976

2. Design Life - 2 years

3. Coverage



TYPICAL CTS ANTENNA COVERAGE FOR THE GIVEN BORESIGHT AXIS IN THE U.S.
(Curves are Constant Loss in Signal Strength)

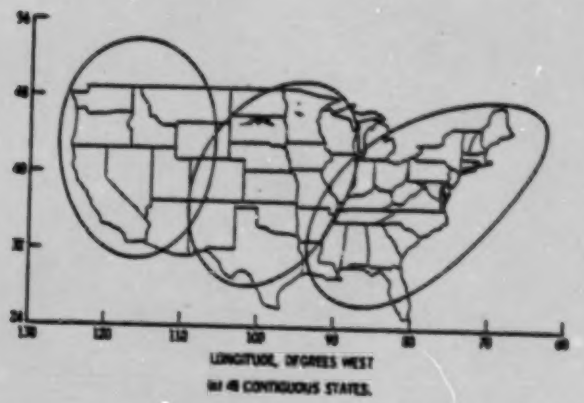
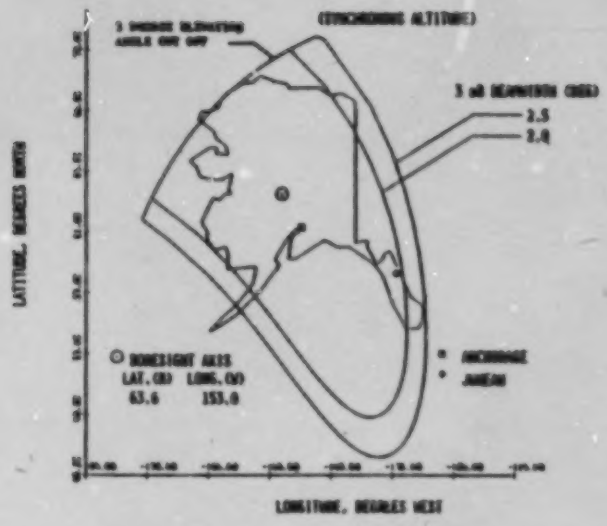


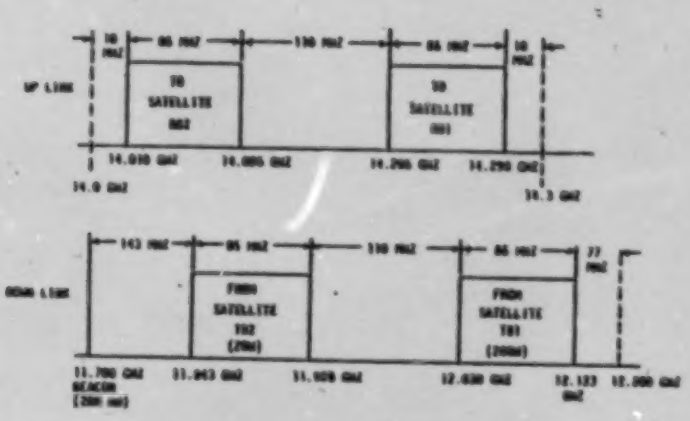
FIGURE 12
CTS (CONT.)

3. Coverage (cont.)



TYPICAL CTS ANTENNA COVERAGE FOR THE GIVEN BORESIGHT AXIS IN ALASKA

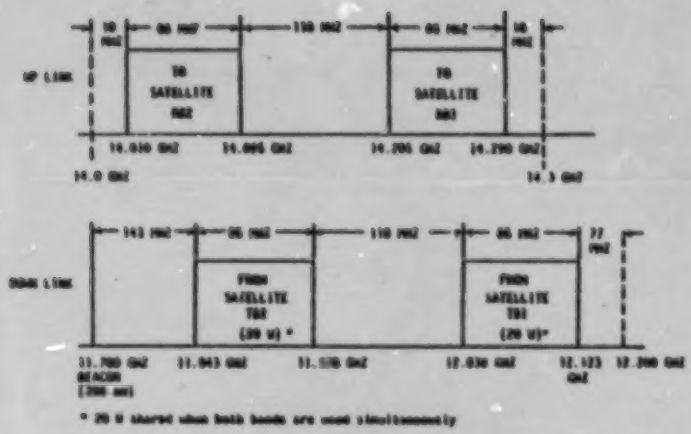
4. Frequency Plan



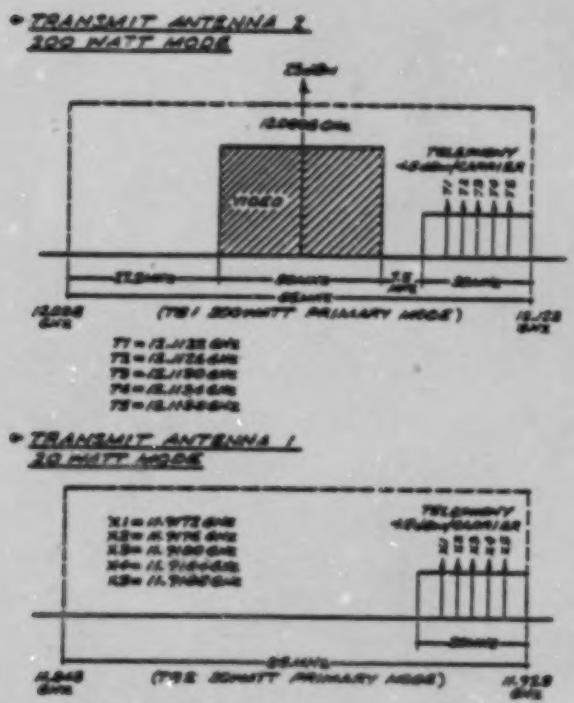
SHF FREQUENCY PLAN, PRIMARY MODE (PM)

FIGURE 12
CTS (CONT.)

4. Frequency Plan (cont.)



SHF FREQUENCY PLAN, SECONDARY MODE (SM)



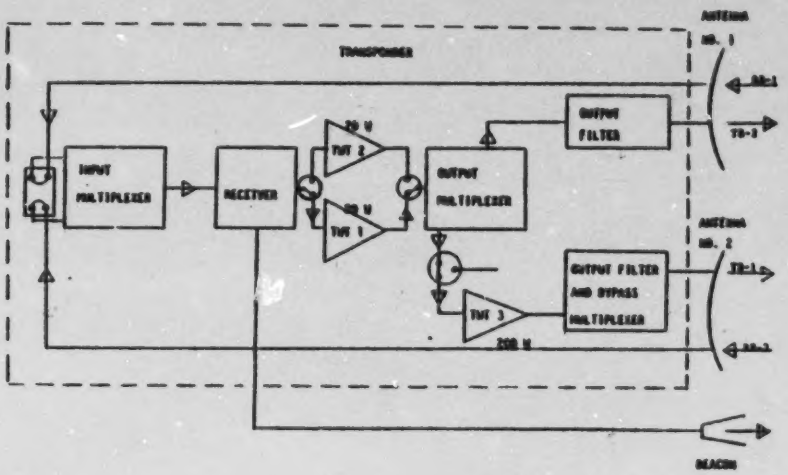
SHF FREQUENCY UTILIZATION PLAN

FIGURE 12
CTS (CONT.)

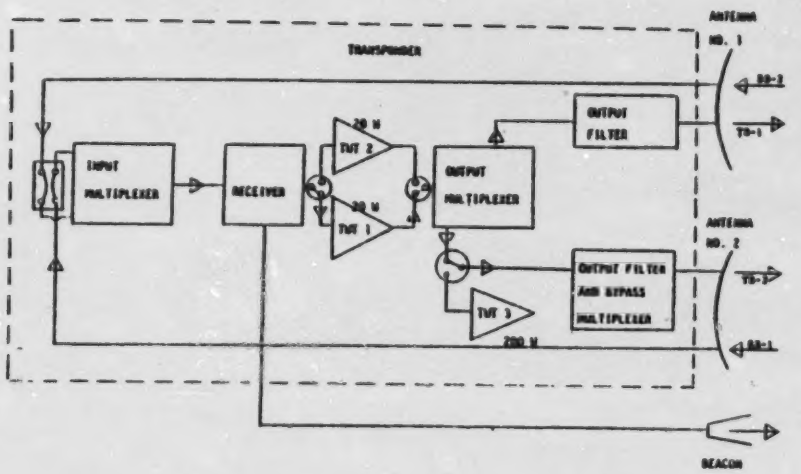
5. EIRP - 50 dBw (20watt Mode); 59 dBw (200 watt mode).

6. Capacity - 2-way video and 2-way audio with appropriate Earth terminals.

7. Block Diagram and Illustration



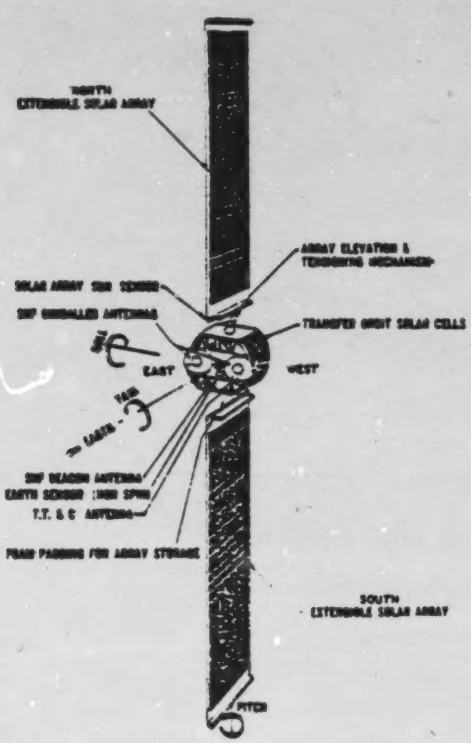
SHF SYSTEM CONFIGURATION FOR PRIMARY OPERATIONAL MODE (PM)



SHF SYSTEM CONFIGURATION FOR SECONDARY OPERATIONAL MODE (SM)

FIGURE 12
CTS (CONT.)

7. Block Diagram and Illustration



CTS - ON STATION

II. GROUND TERMINALS

The subject matter of this section addresses questions posed regarding Ground Terminals. The format followed herein will be based on particular questions and the particular question being addressed will be stated. In considering the particular questions the impact that the answers to each of the individual questions have upon each other, and the effect of unknown regulatory policies or System Operations requirements upon the particular answers must be considered. Where certain considerations which will have impact on these answers are identifiable, they will be identified and discussed to the extent practicable.

II-1 What is the estimated cost of resiting the ATS-6 terminals that NIE has already purchased and installed for previous experiments on ATS-6, from the Rocky Mountain Region to Appalachia? Within the Rocky Mountain Region? Within Alaska?

To answer this question the first step taken was to identify the major cost elements associated with resiting. The cost elements which will be considered as primary factors in determining costs associated with relocating existing terminals fall into 4 general categories, these are: disassembly, shipping, assembly, and administrative. The first three categories are amenable to per-site consideration, while the fourth will represent an aggregate system associated cost which would be allocated on a per-site basis, or retained for consideration as a "system" cost.

The elements of each category have been identified as follows:

DISASSEMBLY

Disassembly
Packing
Refurbishing or reconstituting new site
# of man days (terminal type) or Fixed Fee contract terms

SHIPPING

System, subsystem, or component level
Tariff schedules (air, truck, train)
Protection/Insurance against vandalism & theft

ASSEMBLY

Local permits
Site survey for LOS, obstructions, possible R.F.I., unique requirements
Protection from vandalism/theft
Fence
Prepare mounting pads
# of man days (terminal type) or Fixed Fee contract cost
Rack assembly of subsystem components
Adjustment, calibration and testing

ADMINISTRATIVE

Instruction on Maintenance & Operation for "new site" personnel
Coordination and planning of shipping and assembly schedules
Possible refiling with F.C.C.

Where possible and practical, reliance will be placed upon actual costs experienced in the institution of the original network.

New or replacement components will be costed at F.O.B. delivery point to eliminate the vagaries of shipping and insurance where possible. Attempts will be made to determine an average labor cost for disassembly,

and for assembly (as a function of terminal type if this factor is found to be a considerable one).

Having identified the cost elements, the next step was to establish a resiting scenario. This was necessary to establish specific costs. This memo documents the components of labor and shipping costs which are representative of the effort required to remove an existing receive only terminal (ROT) from the "Rocky Mountain States" region, pack such terminal and transport it to Denver Colorado, from where it would be shipped, via a Van Line, to one of several major cities in the "Appalachian" area; a distance of about 1200 miles. From this terminal point, the packaged ROT would be transported to its new site, unpacked, and assembled.

Several assumptions are implicit in the scenario which has been used for the costing basis. The first, is that it is assumed the appropriate shipping containers have been designed, and are available at the existing site. The second presumes that dismantling of the existing site will only be engaged in to such an extent as to facilitate reasonable packaging. That is, that the reflector will not be dismantled, but only the feed will be removed; and further, that the foundation timbers will be removed intact, with the base mounting hardware remaining attached. Teams comprising 3-men are assumed throughout.

With the scenario established detailed cost elements were established as follows:

	Travel to Existing Site[1]	6 man hours
	Remove Fence Fabric and Gate	1 man hour
	Disassemble Antenna Reflector	2 man hours
(A)	Remove Mounting Timbers/Fence-Posts	3 man hours
	Regrade/sod Site	1 man hour
	Package Antenna/Feed/Receiver/Fence Fabric/Gate	6 man hours
	Truck/Fly to Shipping Point [2]	$200 per ROT
(B)	Shipping Cost[3]	$320
	Delivery to New Site	$50 per ROT

	Unpack & Check (Damage or Loss)	2 man hours
	Prepare Site for Antenna Mounting(4)	6 man hours & posts
	Install Fencing/Gate	2 man hours
(C)	Install Antenna Reflector/Feed/Cont'd	6 man hours
	Rack Mount Receiver	1 man hour
	Adjust Calibrate & Test	8 man hours

(D) Site Survey and Administrative Matters for FCC Filing?

The above scenario assumes that weather will not be a significant factor, and that disassembly will not be hampered by any accrued weathering of Components (rust).

(A) - Total service contract for area wide removal could be more economical.

(1) - Cost highly variable as a function of point of origination W.R.T. site.

(B) - Consider accumulation and mass shipping to one or two central sites where functional checkout, repair and storage functions could be separately obtained. Reshipping to individual - "New Sites" - of "checked out" equipment would originate from here.

(2) - Variable as related to proximity to a common carrier depot city.

(3) - See text for explanation of factors.

(C) - Variability as to whether on site labor is use, versus travel to site from present location of skill/experienced labor.

(4) - Includes laying base for reflector, and placing fence posts in ground.

SHIPPING COSTS

The determination of the shipping cost estimates has been made on the assumption that shipping in "cushioned" vans is desirable.

Therefore, published tariffs in use by furniture moving lines were used as a basis for costing. While these rates are higher than common

carrier truck line rates, it should be kept in mind that actual "Van Line" rates could be substantially lower if the property to be moved can properly be classified as Government Property. Moreover, the "volume" of the packages to be shipped is only of secondary importance, and rates are given as dollars per hundredweight based on the weight of a shipment. For example, the rate per hundredweight associated with a 500 lb. shipment is higher than the rate per hundredweight of a 2000 lb. shipment. Clearly then, it is economically desirable to aggregate the items to be shipped at one central point, and then ship them to another central end point. In addition, the rate per hundredweight per mile is lower over long distances than over short distances.

The shipping weight of an ROT plus fence,mesh and gate is expected to be 800 lbs. The average distance to a "resite" from Denver will be about 1200 miles, resulting in a cost of $40.00 per hundredweight. The resulting shipping cost will average about $320.00.

TOTAL LABOR COST

It is assumed that 3 men will make up a "team" for the purpose of removing and for installing the ROT. Cummulative man hour estimates sum to 44 man hours. Allowing $15.00 per man hour as a reasonable cost, and rounding to 8 hour increments the result is $720.00 in labor costs per ROT resiting.

ESTIMATED TOTAL COST

If allowance is made for the cost of personnel travel, excluding meals and lodging, in the amount of $100.00 per week, then the total cost of resiting an ROT terminal in the Applachian region, from an original site in the "Rocky Mountain" Region, should be slightly less than $1400.00 per terminal.

SUMMARY

The nominal cost of resiting an ROT from the Rocky Mountain region to the Appalachian region is about $1500. This cost is based only on those factors which are uniquely associated with such resiting and does not in-

clude the costs associated with site survey, FCC filings, environmental impact statements, and general administrative cost. These later elements would be associated with the "new" site in any event, whether a new terminal was to be procured on an "old" terminal was to be "moved in". Therefore, these costs are not properly attributable to a resiting evaluation, but must be considered nevertheless as part of the total cost of establishing a new site in the Appalachian Region. The following table presents an overview of the costs associated with the various elements of a resiting operation.

Old Site	360
Shipping	570
New Site	360
*Site Survey	1000-1500
*F.C.C. Filing	?
*Environmental Impact	?
*General Administration	?

* Not attributable to resiting comparison for "old" versus "new" terminal equipment.

The distinction between attributable and non-attributable costs is not always clear. For example, where an existing terminal is mounted to a building roof, costs of $500 to $700 dollars may be incurred in merely bringing the terminal down to ground level. In addition, the antenna mounting hardware may have been welded to the building's structural steel in order to withstand wind-loading. In such circumstances, the cost of dismounting, and refurbishing the building roof to its original condition could be in the $3,000 to $4,000 range. In this situation, the cost would be attributable to resiting if no obligation to remove and refurbish exists; but where an obligation to remove and refurbish exists, such costs would have to be incurred in any event, and would not be properly attributable to resiting. So too, the variability in the complexity with which the intrusion into the building wall was or is required to be made in order to accommodate the coaxial cable connecting the "outdoor" antenna to the "indoor" receiver, is an uncertain element of costs. Whether this variable is attributable, is again a function of existing obligations to remove and/or refurbish the

old site, as well as the requirements for complex installation at the new site, notwithstanding the source or type of terminal equipment to be installed.

Alaska

Having reference to a memorandum from one Ted McIntire to one Robert W. Walp, dated June 16, 1976, and supplied as reference material by Mr. Kevin Arundel, the cost estimated for removing "all ATS-6" equipment is given as $35,250.

The assumptions upon which this number is based are not fully documented, but the number of terminals being addressed are readily determined to be 19. The per terminal cost is determined to be about $1900 including labor and associated costs, extra "state" freight, transportation, and packing. Approximately $1050 is allocated for labor and costs which is significantly greater than the amount allocated for a "Rocky Mountain" to "Appalachian Region" resiting discussed in an earlier section. The disparity which exists is not so much related to daily man hour costs, but rather to the number of man hours allocated to the task. It is not known to what extent weather is considered as a factor in computing man hours allocable to dismantling and packing. The difference in estimates is significant in this regard, i.e., 56 man hours in Alaska and 24 man hours in the "Rocky Mountain Region." Moreover, the costs cited are for removing the ATS-6 terminals and do not include any cost elements for reinstallation at some other place. In addition, the shipping scenario is unknown, and consequently we are unable to determine whether shipment to a central collections point was envisioned or whether shipment envisioned collection at a particular port for transportation outside of Alaska. A cost factor of $5k to $10k was allocated to "outside freight," but again, the origination and destination points assumed are unknown.

Roof Mounted Antenna

The best estimate obtainable, based on conversations with Mr. Ogden and Whalen, are that those terminal equipments designated as assigned to Public Broadcast Stations, are the equipments which have been roof mounted. The consequences of this identification are that the costs of merely removing

these terminals may be significantly greater than costs associated with ground level installations. An estimate of this differential cost is $500 to $700. All of these terminals are ROT's. They are:

Tempe, Arizona	Tucson, Arizona
Boise, Idaho	Moscow, Idaho
Pocatello, Idaho	Albequerque, New Mexico
Provo, Utah	Portales, New Mexico
Denver, Colorado	Salt Lake City, Nevada
Pueblo, Colorado	Las Vegas, Nevada

II-2 How does this compare with purchasing new equipment and using the present equipment as spares? What is the estimated time for the manufacture and delivery of new equipment? Is there a mix of the two types that makes sense?

First, comparing costs of new equipment, it is presumed that the existing HP receivers will be used, and further, that existing antenna reflector mounts may, or may not be used.

A competitive price for a 10 foot receive only antenna reflector and feed assembly, operating at S-Band is $1500. Mounting hardware will cost $2,465. for manual, and $4,015. for a motorized arrangement with digital read-out. These are per-unit prices which may be reduced by 15% to 20% for quantities of 10 units, and from 25% to 30% in quantities of 50. Restricting the comparison to S-Band alone, it is seen that comparative costs for ROT's would be about $4,000. for new equipment which would operate with existing HP receivers, and utilize a manual mount, versus a $1,500. cost for resiting.

Estimated time for delivery of new S-Band equipment, is highly dependent upon quantities ordered. As of the present time, reliable estimates have been in the order of 5 months to first item delivery.

A mix of "old" and "new" stations which makes sense is predicated on a number of considerations and variables. Fundamentally speaking they all relate to either cost or time required for implementation. Since the question is limited to S-Band (ATS-6), the stations must be in place so that a reasonable useful service period is achieved. ATS-6 is currently beyond its design life thus time is a key factor.

As far as cost is concerned, the optimum mix would be a minimum cost mix. The cost of a mix can be expressed as:

$$\text{Cost} = C_R N_R + C_N N_N$$

Where;

C_R = Cost for relocating a terminal

N_R = Number of terminals which are relocated

C_N = Cost for a new terminal

N_N = Number of new termianls

As far as time is concerned, the time required to place a mix of terminals in service can be expressed as:

$$T = T_R;\ T_R > T_N$$

$$= T_N;\ T_N > T_R$$

Where;

T_R = Time required to place relocated terminals in service

T_N = Time required to place new terminals in service

The above relation assumes that relocation and manufacturing of new terminals will commence at the same time.

To find the best mix, one must use the above relationships iteratively to obtain various values for cost and time for comparision and decision making. In short one cannot arrive at a best mix easily. Total scenarios must be established to which the above expressions are applied. Also, since the best solution can only be achieved iteratively numerous scenarios must be examined.

II-3 What is the cost of converting the ATS-6 terminals to use commercial frequencies or to use CTS frequencies for receive only (video and voice); receive (video and voice) and transmit voice/data; and, receive/transmit video and voice?

This question will be addressed functionally, that is, first for receive only, and then for the 2 Receive/Transmit functions.

Receive Only Video & Voice - Commercial Frequency, C-Band

Figure 13 presents functional block diagrams of three possible modifications to the basic S-Band receiver configuration which will allow conversion of the S-Band terminal to use commercial C-Band frequencies.

Table 1 presents a base power budget for these three C-Band configurations as well as a power budget for the existing 6' configuration being used iwth CTS, whose functional block diagram is shown in Figure 14.

Table 2, summarizes the resultant C/KT which would be available with each receiver configuration (A thru D) as a function of which satellite is being considered as the repeater.

Annotated beneath each of the C-Band modified configurations (B, C, and D) is the differential cost accrued due to the conversion, with the basic S-Band configuration used as the baseline. A significant part of the 15' reflector configuration cost is the requirement for a replacement motorized mount. The possibility of "Trading" in existing mounts and reflectors is not considered as a practical way to reduce the incremental costs of upgrading.

The existing S-Band segmented reflector configuration has been shown to be capable of modification to operate at C-Band. This result is obtained by providing a $55^{o}k$ parametric/amplifier and a double balanced mixer which will convert the received C-Band frequency to the appropriate RF frequency used in the HP receiver. ORI's sources indicate that the paramp cost is about $25,000; the mixer cost is about $150. Also that the performance of the segmented reflector at C-band is about equivalent to a solid 6' diameter reflector; that is, a loss in gain of about 4.5 dB is taken. The resultant receiver figure of merit is about 18 dB (G/T). The service provided under these conditions has been subjectively rated as "good". Replacing the segmented reflector with a "solid" reflector, one could trade increased antenna gain against system noise temperature, and could get the same results with a $140^{o}k$ to $150^{o}k$ paramp. The difference

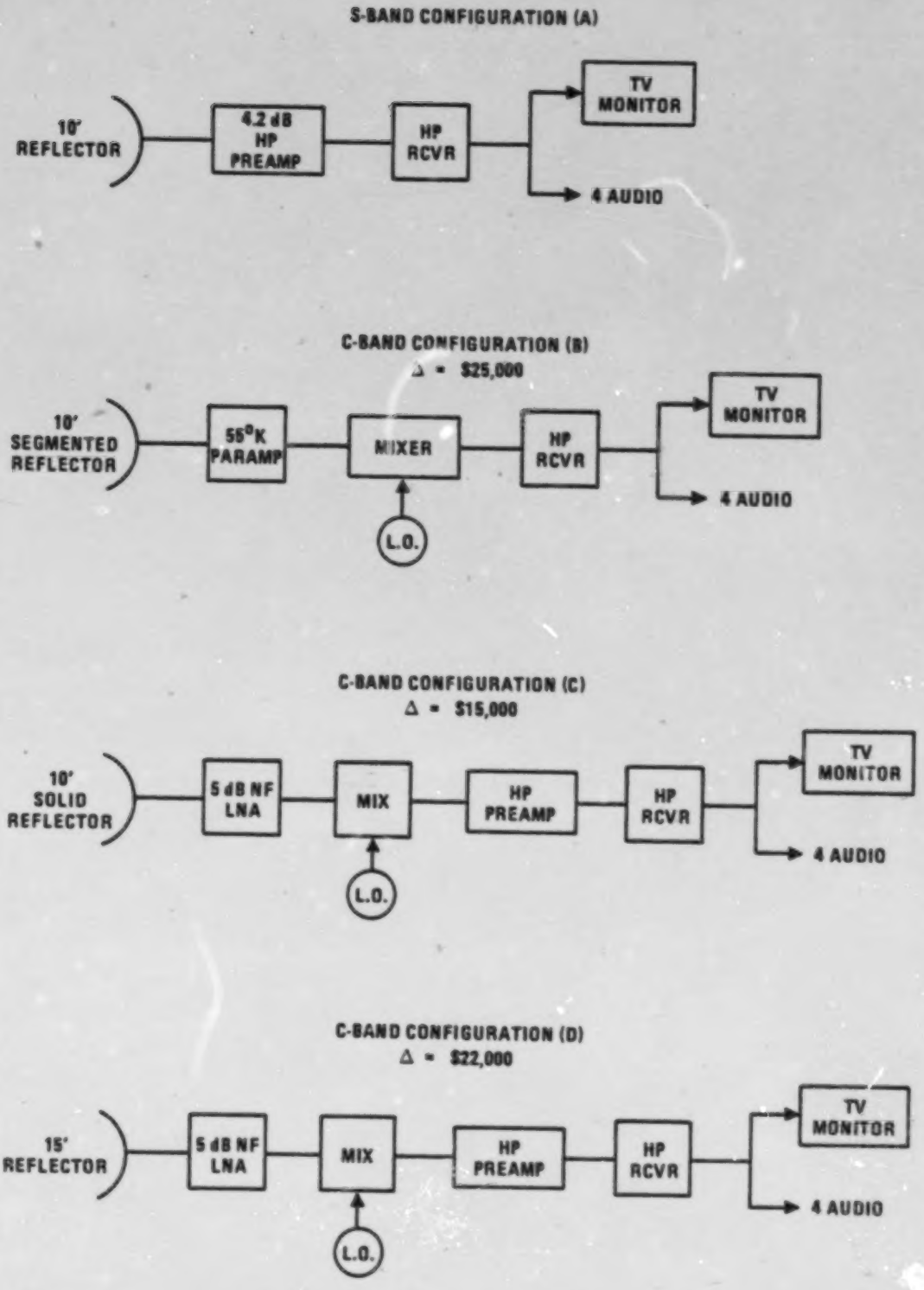


FIGURE 13. C-BAND CONVERSION OPTIONS

TABLE 2.1

BASE POWER BUDGET

EIRP = 0 dBw

Elevation = 10^{o}

	Configuration A (2.569 G_c)	Configuration B (4 G_c)	Configuration C (12 G_c)	Configuration D (4 G_c)	Configuration E (4 G_c)
Free Space Loss	192.8 dB	196.65 dB	196.65 dB	196.65 dB	206.1 dB
Atomic Loss	0.15 dB	0.2 dB	0.2 dB	0.2 dB	0.5 dB
Antenna Gain	35.62 dB	35.03 dB	39.48 dB	42.86 dB	40.16 dB
C (Carrier Power)	-157.33 dB	-161.82 dBw	-157.37 dBw	-157.37 dBw	-166.44 dBw
T (^{o}K) Amp	472^{o}K	55^{o}K	627^{o}K	6[illegible]^{o}K	627^{o}K
10 = αT (^{o}K) Antenna	75^{o}K	75^{o}K	55^{o}K	55^{o}K	55^{o}K
Total (^{o}K)	547^{o}K	130^{o}K	682.06K	682.06K	527^{o}K
Total T (dB)	27.4 dB	21.1 dB	28.34 dB	28.34 dB	27.22 dB
KT	-201.45 dBw/Hz	-207.5 dBw/Hz	-200.26 dBw/Hz	-200.26 dBw/Hz	-201.30 dBw/Hz
C/KT	44.12 dB/Hz	45.68 dB/Hz	42.89 dB/Hz	46.27 dB/Hz	34.94 dB/Hz
G/T (dB/K)	8.22	13.93	11.14	14.52	12.94

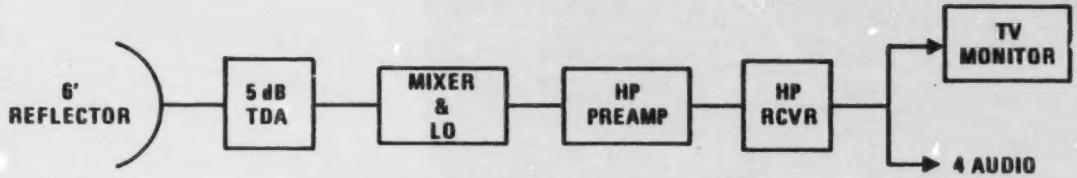


FIGURE 14 K-BAND CONVERSION OPTIONS

TABLE 2.2
RESULTS USING BASE POWER BUDGET

- ATS-6 EIRP = 52.7 dBw (2.569 GHz)

  (A)

  C/KT 96.82

- WESTAR EIRP = 33 dBw(4GHz)

  (B) (C) (D)

  C/KT 78.68 75.89 79.67

- RCA B-2 EIRP = 32 dBw (4 GHz)

  (B) (C) (D)

  C/KT 77.69 74.89 78.67

- COMSTAR EIRP = 33 dBw (C-Band)

  (B) (C) (D)

  C/KT 78.68 75.89 79.67

- CTS EIRP = 50 dBw 12 GHz

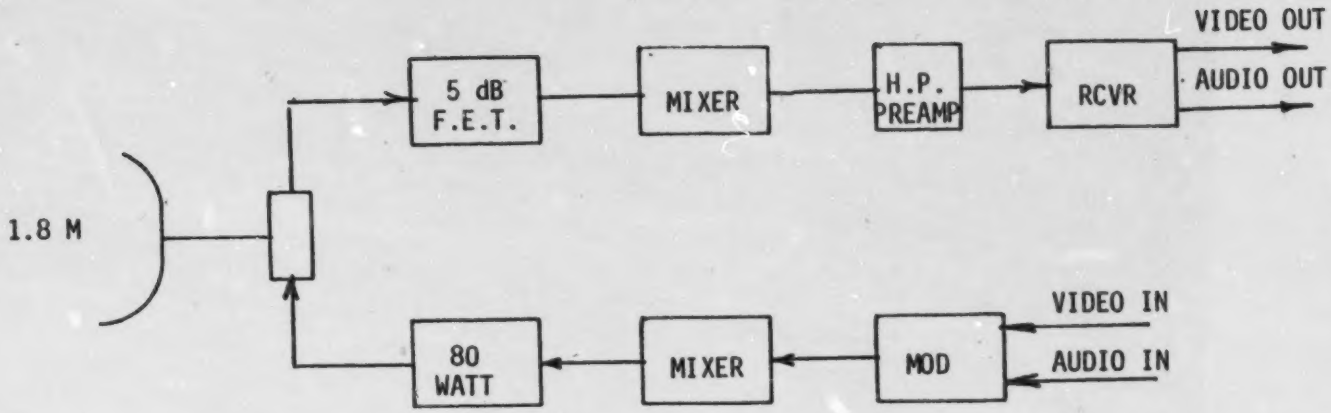
  (E)

  C/KT 84.94

in costs resulting from upgrading the reflector (+$1500) when weighed against the differential cost of the higher temperature paramp ($25k vs. $12k) results in the same available performance with a net savings of about $10k. Added to the consideration, is the fact that the Proposed Domsat EIRP's are on the average, at least 4 dBw higher than the ATS-6 EIRP at 4 GHz. When this is taken into account, it is seen that it may be possible to obtain adequate performance using the segmented reflector and a paramp in the range of 140^{o}k to 150^{o}. BUT, considerations other than technical are a limiting factor. In particular, present FCC regulations require that receiving terminals operating in the C-Band frequency range, shall be no smaller than 9 meters (30 feet). However, hearings are scheduled in early December (Rulemaking; 2725) to examine the possibility of revising this regulation to allow smaller minimum diameters. It is this writers opinion, however, that no receiving antenna diameter lower than 4.5 meters (15 feet) is likely to be permitted. Hence, notwithstanding the technical practicability of modifying existing equipment to operate in the C-Band frequency range, in the receive only mode, such operation is likely to be precluded due to regulatory prohibitions. An additional question which is expected to be addressed at the Rulemaking hearing, is the feasibility of allowing "undersized" receiving terminals to operate under conditions wherein the rights to complain, or bring interference mitigation actions are waived as a condition of licensing. No prognosis can be made on the ultimate resolution of this question.

Receive Only - Video and Voice, Commercial Frequencies-K-Band

The present segmented reflector design is not adequate for operation above C-Band. However, certain equipment adaptations, used with the existing HP receiving equipment, have been shown to provide excellent service in demonstrations performed with the CTS satellite. This demonstration utilizes an antenna reflector of 1.8 meters in diameter, and an image enhancement/image rejection mixer to enable TV reception from CTS using the HP receiver. The present configuration, which is set up at GSFC, is under the control of Mr. A. Whalen, and additionally, provides for a 80 watt transmit capability as well. See Figure 15.



REFLECTOR & PEDESTAL	$2750
FET PREAMP	2500
MIXER, EACH	2500
HP PREAMP	2100
HP RCVR	2000
80 WATT AMP	6000
TOTAL EST. COST	$20350 & MODULATOR

FIGURE 15. BASIC CTS RCV/XMIT CONFIGURATION

The cost of a K-Band antenna (6 feet) for receive only is about $900, and increases to about $1400 for receive and transmit. Motorized mount costs have been quoted at $2795. These prices are for single unit quantities. In quantities of 50 or more, a 25% to 30% price reduction would apply.

It should be pointed out here, that the "successful demonstration" referred to, using this modified equipment, was shown to be possible with a CTS satellite, whose EIRP is 59 dBw. The maximum EIRP to be expected from the SBS DOMSAT, which will operate in K-Band, is 43 dBw, and therefore, useful terminals intended to operate with an SBS DOMSAT will be required to meet more demanding performance requirements.

The Comsat Corporation is presently engaged in building a small K-Band receive and transmit terminal for a demonstration experiment involving CTS. This terminal is intended only to transmit and receive up to 4 voice channels. Conversations with Mr. J. Kaiser, of Comsat, who has designed and built a number of K-Band experimental terminals have led to some valuable information. According to Mr. Kaiser, a receive only terminal, operating in K-Band, which will provide TASO II television quality, or better can be available for a cost of about $12.5k. This configuration consists of an 8' diameter reflector, a 600^{0}k FET front end (G/T 20 dB) and a Farinon FM demodulator. This configuration should give adequate television reception when used with a 43 dBw ERP satellite, such as the proposed SBS DOMSATS. However, it is not known at this time, whether SBS will provide television broadcast service, or, if indeed, they would allow independently designed and owned receiving terminals to operate within their system.

Receive Video/Voice, Transmit Voice/Data (C-Band and K-Band)

The present terminals are technically capable of modification to meet these requirements at frequencies up to C-Band. Figure 16 depicts the functional components required to be added. The primary consideration when evaluating the use of these terminals with future commercial Domestic satellites is one of system operator interface requirements.

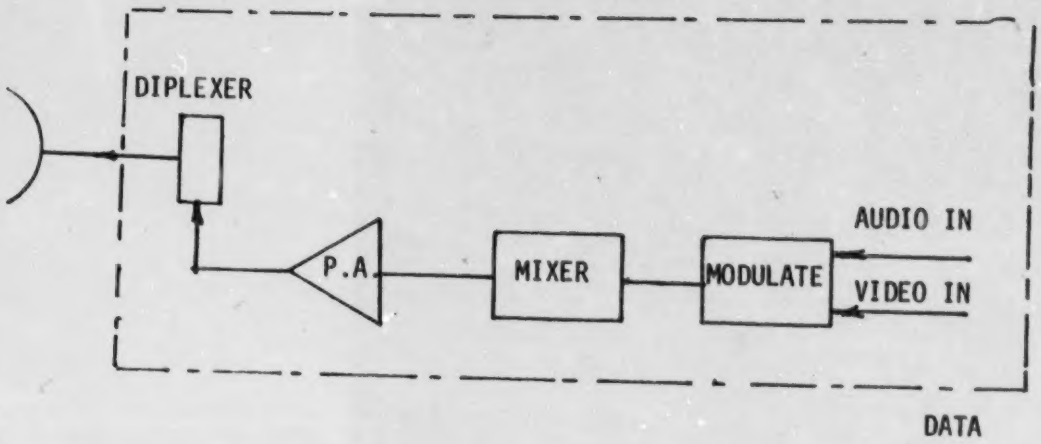


FIGURE 16. ADDED EQUIPMENT FOR TRANSMISSION

Assuming that consideration is being given to leasing an entire transponder, many of the problems of multiple access such as power sharing, modulation type and parameters, and cross channel interference are significantly lessened. The ability to share transponders with other users, on the other hand, imposes operational and technical constraints upon "small terminals", exclusive of any regulatory prohibitions mentioned earlier. The nature of the "System Operator" restraints will be more fully identified and explored at the upcoming seminars.

Some general observations which help to explain how the multiple access parameters, and sharing plan on a particular transponder affect ground terminal costs will be discussed in order to provide some background.

The mode of operation in almost all experimental or demonstration satellite programs has been one where a single user has available to him, all of the power transmitted by the satellite. In an operational system, more than one user will be attempting to share the satellites power at the same time, consequently any one carrier's power will be reduced in proportion to the number of simultaneous accesses, plus an additional factor due to limiter suppression effects; this suppression factor typically varies from 1 to 6 dB. Another result of multiple access operation is that the signal "quality" is subject to degradation as a result of intermodulation products formed by the interaction of the multiple signals in the satellite repeater, which is a highly non-linear device. Much of these difficulties are obviated by a time division multiple access system, whereby no more than 1 carrier is accessing a transponder during a present period of time. However, the cost of equipping users with appropriate TDM modems is prohibitive at this time for all but large volume users of satellite services.

It all boils down to the fact that a terminal whose technical characteristics would result in the provision of acceptable service under single access (demonstration) conditions, is likely to be 4 to 8 dB "short" under operational conditions.

Receive and Transmit Video and Voice (C-Band and K-Band)

The very same considerations mentioned above are applicable to these configurations as well, with the additional factor of higher cost attributable to the modulation equipment required for transmission of television and voice subcarriers. Of course, additional attention will also have to be paid to the transmit/receive feed design as well. Additional information will be forthcoming as a result of the planned seminar.

II-4 What are the costs and possible advantages of converting existing ATS terminals to multifrequency operation for the configurations noted in item II-3 above, e.g., ATS-6/CTS, ATS-6/commercial?

It can be stated, unequivocally, that the existing 10 foot diameter segmented reflector is not ammenable to use at CTS frequencies (K-Band). Therefore, it would be impractical to consider multifrequency use where one of the proposed frequencies is above C-Band.

Multifreqquency use is technically feasible for the pair of frequencies, S-Band/C-Band, in either of the functional configurations examined in Paragraph II-3, subject of course to the same regulatory and system operator constraints mentioned therein. Putting these aside for the moment, and considering only the technical aspects, the greatest possible advantage would accrue where multifrequency reception only is being considered. The potential advantages, would be:

- Ability to operate with more than one satellite precludes outages due to failure and scheduling, as well as allowing some change of programming as a function of time.
- Ability to take advantage of competitive tariffs among DOMSAT services.
- Allow amortization of ground terminal investment over longer period of time.
- Advantage of "free" time on Experimental Satellites in S-Band.

- Ability to use either of the ATS-6 downlink frequencies.

The modification itself would require installation of a switched feed and the addition of a low noise amplifier for C-Band reception. Recalling the consideration of Paragraph II-3, such modification should be attainable at a cost of about $15,000. per terminal. See Figure 17.

In order to consider multifrequency receive/transmit functions using modified presently existing equipment, it is implicit that the very same satellite be capable of providing multifrequency service. Only ATS-6 presently provides this capability, and no Domestic satellite is presently planned to have such capability. Recall, however, that Hybrid C-Band/K-Band DOMSAT designs are being considered for the future. Alternatively, multiple satellite use could be considered, but would require more sophisticated mounting and pointing equipment, which would add $5,000 to $7,000 to the cost; and such multiple satellite use would require compatibility between each multiple access scheme and modulation parameters. If such compatibility did not exist, then the added costs of an alternate L.O. ($350-$600) and receiver/demod ($3,500 to $4,000) would have to be incurred.

At this point, some of the cost relationships which exist as a function of receiver noise temperature and antenna size should be examined. An understanding of Figure 17 is essential to the ability to evaluate optimum receiver configurations for any particular purpose, at any particular frequency. By appreciating the cost factors which go into a determination of a particular receiving configurations figure of merit, expressed as G/T, the shifting burdens of subsystem performance between satellite and ground system, and the alternative costs, can be understood. Figure 18 is instructive insofar as relationship are concerned, and the cost figures should not be taken as definitive. As noted in the caption, the particular relationship shown are derived for an S-Band Receiver Terminal. However, for any particular frequency band, the same general type of relationship can be derived. Similar cost relationships can be derived for transmitting terminals with transmitter power, prime power requirements, and antenna size as parameters. It is clear however, that increased receiver figure of merit, irrespective of the combination used to attain it (i.e., reflector size and noise temperature) is only attainable at increased cost, once the optimum

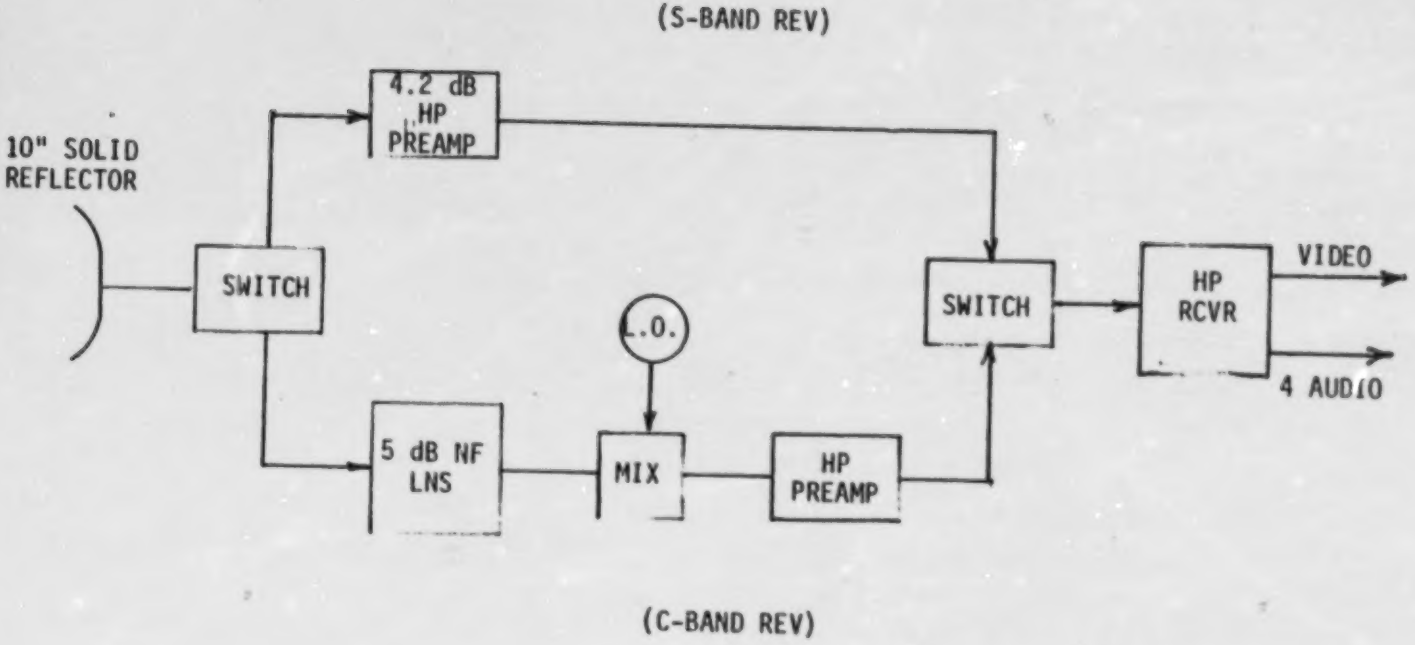


FIGURE 17. MULTI-FREQUENCY CONFIGURATION

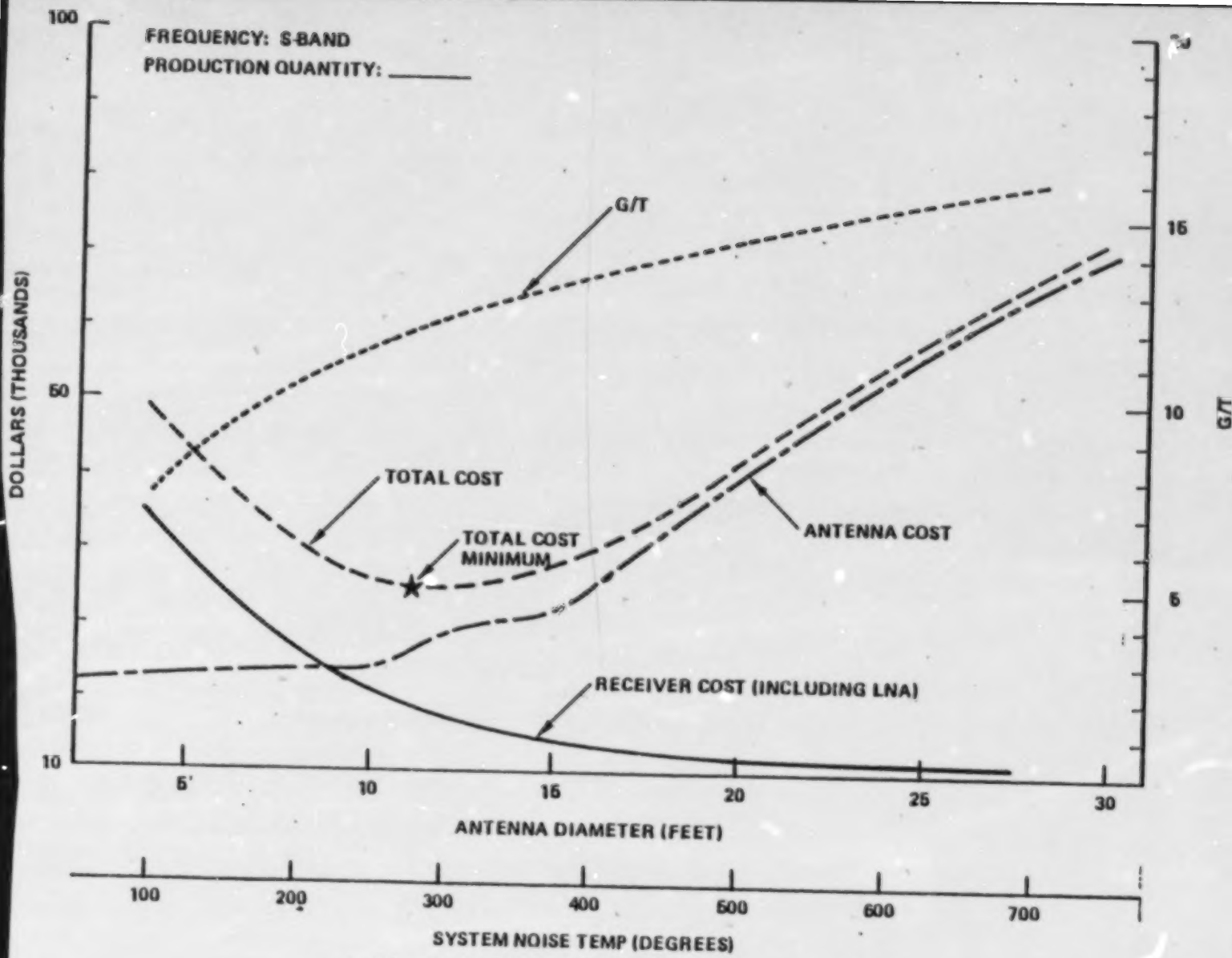


FIGURE 18. BROADCAST GROUND TERMINAL COST/PERFORMANCE

cost point has been reached. Consequently, if the resultant optimum cost G/T will not provide adequate service, the alternatives are either less cost effective receiving terminals or increased satellite repeater performance in the form of effective radiated power-EIRP.

Figure 19 depicts this Receiver/Satellite performance interrelationship for specific reflector sizes, where the satellite repeater is at synchronous altitude and is transmitting on the downlink at 4 GHz. A choice is available based upon desired quality of service for a color television picture transmission. In general, an 18 dB difference in required EIRP represents the range of receiver performance between the lower bounds of TASO II quality, and the upper range of TASO I quality. It should be remembered at this point, that the TASO quality standards are primarily subjective standards which for the purposes of this evaluation are related objective power budget calculations. The base power budget which was used to derive the relationships of Figure 19 are presented in Table 3.

II-5 What is the probability of small Earth Stations in the 12-14 GHz band costing under $20,000 for video receive and audio/data transmit-receive, using probable commercial satellites of the next decade?

The key to cost evaluation of such terminals lies in the characteristics of the "Commercial" satellite being considered as the repeater. At this time, only SBS is committed to a satellite repeater operating in this band for Domestic service, while INTELSAT is expected to provide some degree of K-Band service to the International Community. It is important to note, at this time, that present experience in this band has been gained with use of the CTS satellite, which provides 59 dBw of effective radiated power; no commercial satellite will be available with anywhere near this ERP. The maximum available ERP, per transponder, is quoted from SBS sources as 43 dBw. The impact of this differential is that ground terminals intended to perform receiving functions will have to have 16 dB greater performance capability to meet the performance presently being obtained via the CTS satellite.

An existing CTS terminal will be used as a basis for estimating the costs of such an improved terminal. This basic terminal is represented by

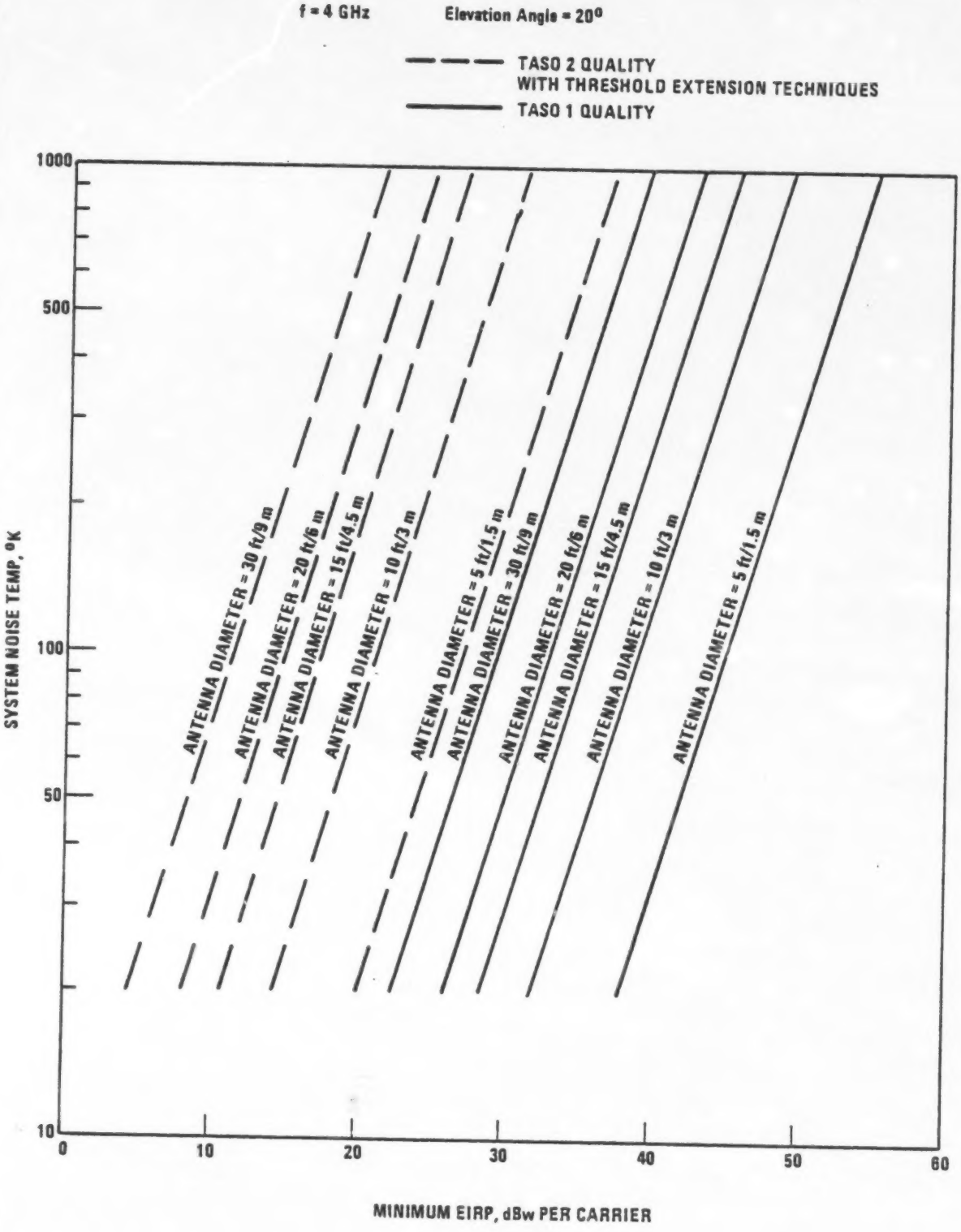


FIGURE 19. VIDEO PERFORMANCE TRADE-OFFS

TABLE 2.3

BASE C-BAND POWER BUDGET

f_c = 4 GHz

Base EIRP	0 dBW
Free Space Loss .[1]	-196.5 dB
RCv. Antenna Gain[2]	33.4 dB
RCv. Signal Power (c)	-163.1 dBW
RCv. System Noise Temperature[3] (dB)	19.0 dB
RCv. Noise Power Density (KT)	-209.6 dEW-/Hz
RCv. C/KT	36.5 dBW/Hz
Received $C/_T$	-182.1 dBW/Hz/oK
Required $C/_T$ for TASO I quality [4]	-138.0
Required EIRP for TASO I quality	+ 44.1 dBW

[1] Slant Range @ 24,600 Statute miles, assume 20° elevation angle

[2] Assume 5' antenna

[3] Ta = 29° K; Ts = T_a + TR where TR is parametrically variable, for this calculation, TR =590 kis assumed.

[4] for TASO I, $C/T \geq -138.0$; for TASO II, C/T - 156.0

the configuration which is presently in existence and operating at Goddard Space Flight Center, and under the control of Mr. Al Whalen. Figure 15. depicts this present installations configuration.

The estimated component costs, as listed on this figure result in an estimated total of about $20,350. Allowing $10,000 for installation and checkout, and audio modulator, the total cost would be about $30,000. Recall however, that a configuration which is 16 dB better is required to match the performance of this terminal when operating with CTS.

Obviously, the question to be asked now, is "what terminal figure of merit (G/T) will give acceptable performance with a commercial satellite providing 43 dBw ERP?" Recall that from earlier discussions, a received C/T of -138 dBw is required for TASO I quality service in a 26 MHz receive bandwidth, and that a C/T of -156 dBw is required for minimum TASO II service.

If we assume a 43 dBw ERP satellite, and a 54 MHz bandwidth, as well as an equivalent noise temperature, the resultant carrier to noise power received would be about 0 dB for a 6' (1.8 meter) dish. A carrier to noise ratio of greater than 10 dB is required for threshold, so on this basis alone, a 10 dB increase in receiver G/T is required to meet this criteria; to obtain this increased performance, the reflector size must be increased to at least 15' in diameter (G/T $\simeq$ 22 dB) with resulting C/T of about -141 dBw. This received level will be able to provide better than TASO II quality even under 10 dB fading conditions. It is seen however, that, should fading occur, the receiver would drop below threshold, and loss of signal would occur. Hence, it is the threshold criteria which is the limiting factor in providing reliable service.

The increase in cost, as a differential, which would be incurred by upgrading the reflector from a 6' diameter to a 15' diameter would be about $7,000, including a larger and more rigid motorized antenna reflector mounting structure.

To summarize, adequate receive video, and transmit audio/data performance will be obtainable with a 43 dBw Commercial Satellite operating at K-Band, by modifying the configuration Figure 15. to upgrade the dish and

mount to a 15' size for a total cost of about $37,000.

Having determined the general performance required for an improved terminal to operate with commercial satellites of the next decade we return to the original question of how the present estimated cost of $37,000 will vary over the next decade. To do this, the following question must be answered: What technology development, if any, in the next five years will result in significant cost reductions for small ground terminals? A seminar originally scheduled for December 1, that would have brought together selected manufacturer of ground terminals to address this very question had to be postponed until January. Therefore the answer to this question cannot be answered fully at this time. However, some observations can be made. If an inflation rate of 7% is assumed for the moment over the next five years, a corresponding average decrease in equipment cost of 19% per year is required to bring the terminal cost below $20,000 in five years or a decrease 13% per year over 10 years. If the rate of inflation decreases from 7% to 4% in the next 5 years the average decrease in cost of equipment would need to be 17% per year to obtain a cost of under $20,000 or over a 10 year period, an average decrease of equipment cost of 11%. Another factor that effects the cost significantly is the quantity of terminals to be purchased. A cost reduction of 30% is possible when the quanity is changed from one unit to 100 units. Therefore the following factors that directly effect the terminal costs are:

1. The rate of inflation
2. The time frame in which purchase is considered
3. The quanity of units to be purchased

II-6 What can be the expected cost of a two-way video Earth Station operating in the 12-14 GHz band with probable Commercial satellites of the next decade?

The only difference between II-5 and II-6 is the capability of transmitting video instead of just audio/data. The configuration in Figure 15. is capable of transmitting either. The cost penalty incurred for the increase in bandwidth needed to transmit video is small enough not to consider and there-

fore $37,000 will be used as the present cost.

As in II-5 it was hoped that the seminar would answer the question of technology developments that could be expected in the next 5 years. Consequently this question cannot be answered fully at this time, but the same observations pointed out in II-5 are directly applicable to II-6.